UNITED STATES DEPARTMENT OF AGRICULTURE

In cooperation with the Nevada Agricultural Experiment Station

DEPARTMENT BULLETIN No. 1218

Washington, D. C. ▼ July 21, 1924

HORSE-FLIES: BIOLOGIES AND RELATION TO WESTERN AGRICULTURE.

By J. L. WEBB and R. W. WELLS, *Entomologists, Investigations of Insects Affecting the Health of Animals, Bureau of Entomology.*

With a Description of the Mature Larva of *Tabanus punctifer*, by ADAM G. BÖVING, *Entomologist, Bureau of Entomology*, and a Description of a New Species, by JAMES S. HINE, *Professor of Zoology and Entomology, Ohio State University.*

CONTENTS.

HISTORICAL.

Blood-sucking flies of the family Tabanidae are very serious pests to horses, cattle, and other domestic animals. In certain cattle-growing sections of the United States, particularly where swampy areas exist, tabanids are pests of great economic importance.

In 1915, requests were received from cattlemen, through S. B. Doten, director of the Nevada Agricultural Experiment Station, for an investigation of the conditions favoring and the methods of controlling an abundance of horse-flies which were causing serious losses on ranches in Nevada. In that year J. H. Clemons, land commissioner for the Union Land and Cattle Co., one of the largest cattle

[1] F. C. Bishopp, of the Bureau of Entomology, directed the investigation, and Director S. B. Doten, of the Nevada Agricultural Experiment Station, cooperated. Most of the determinations were made by Prof. J. S. Hine. The junior author conducted the field work in 1919. In the field, Rufus Ogilvie assisted in 1917, Noble Waite in 1918, and Harold Whalman in 1919.

R. W. Wells, the junior author, resigned July 24, 1923.

67887°—24——1

companies in Nevada, in a communication to Director Doten, stated that the flies were so numerous that they prevented the cattle from putting on flesh as they should, and that at times it seemed as though his company was more engaged in feeding flies than in feeding livestock. He stated that during the haying season flies swarmed over the horses, causing frequent runaways and serious accidents. Mr. Clemons believed, too, that the flies were active agents in spreading anthrax.

In 1915 F. C. Bishopp, directing the investigations of insects affecting the health of animals, Bureau of Entomology, United States Department of Agriculture, made a preliminary investigation of tabanid conditions in Nevada. In Antelope Valley, on one of the ranches visited, many cattle were dying, presumably from anthrax, and there was good evidence that blood-sucking flies had much to do with the transmission of the disease. Mr. Bishopp found tabanids to be serious pests to livestock at Deeth, Nev., and at other localities where there is considerable swampy land.

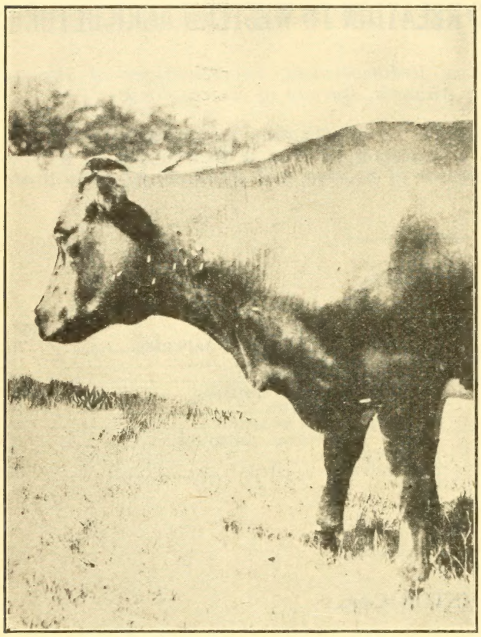


FIG. 1.—Horse-flies feeding upon milk cow.

In August, 1916, plans were completed with the Nevada Experiment Station for a cooperative project on an investigation of tabanid conditions. The senior author was chosen to conduct the studies in the field. Several localities were considered for field and laboratory studies. None seemed so well adapted as a large ranch occupying practically the entire Antelope Valley, lying partly in California and partly in Nevada, with headquarters at Topaz, Calif. The officials of the company, with major headquarters in Reno, Nev., were very anxious for the investigation. W. W. Cunningham, local manager, offered much in the way of convenience and assistance in the work. Several species of Tabanidae were very abundant in the valley and breeding conditions were apparently ideal.

The extent of the investigation, limited by lack of funds, is of more than local importance because several of the species studied are of rather wide distribution. It is hoped that the results may be an aid in much needed tabanid studies in other parts of the United States.

Because of the severe winter climate, the field studies were discontinued during the winter months.

INJURIOUSNESS AND ABUNDANCE.

LOSS OF BLOOD.

The loss of blood sustained by animals attacked by blood-sucking flies is considerable. It is estimated that eight flies of *Tabanus phaenops* Osten Sacken, or "greenheads," having fully fed upon an animal, take altogether 1 cubic centimeter of blood. *T. punctifer* Osten Sacken, a fly still larger, will take more blood than *T. phaenops*. During a season when tabanids are abundant, very commonly as many as 25 to 30 greenheads and 8 to 10 adults of *T. punctifer* are seen feeding on one cow (fig. 1). Considering that it takes a fly only about eight to ten minutes to complete its meal of blood, and that during one day an average of 25 to 30 flies may feed on the animal for six hours, the loss of blood could amount to 100 cubic centimeters in one day. This estimate is conservative. Many isolated animals, horses in harness, and animals too weak to fight the flies vigorously suffer a greater loss in blood than this.

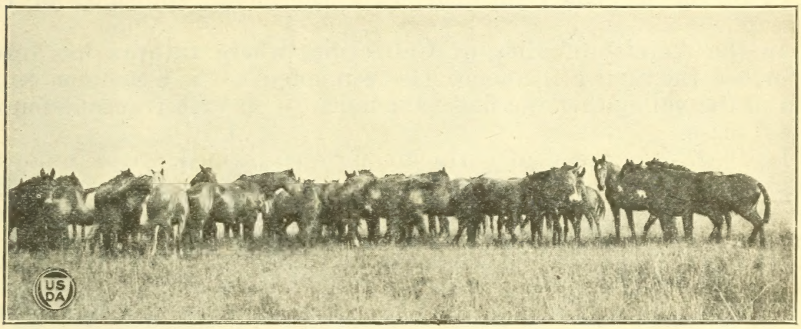


FIG. 2.—Horses and mules grouped together for mutual protection from horse-fly attack.

LOSS OF FEED.

Another way in which the flies cause an important loss is by interfering with the feeding of the stock. During the time of day when flies are very abundant, from about 10 a. m. to 5 p. m., the horses and cattle cease feeding and bunch together for the purpose of fighting the flies (fig. 2.). In addition to the loss of feed during this bunching of the animals, many wounds result from hooking and kicking, and these become portals of infectious diseases or infestations by fly maggots. J. H. Clemons and W. W. Cunningham, cattle company officials, stated that the flies seriously retarded the fattening of the cattle.

CAUSE OF RUNAWAYS.

A considerable loss due to the flies is that from runaways of horses in harness. Mr. Clemons refers to several such accidents resulting in casualties as well as destruction to harness, machinery, and fences.

CARRIERS OF DISEASE.

Possibly even more serious than these losses is that due to various diseases transmitted and disseminated among domestic animals by tabanids.

In Louisiana and the southeastern part of Texas certain tabanids are popularly called "charbon flies." Mitzmain (*6*)[2] very clearly demonstrated in the Philippines that *Tabanus striatus* Fab. carried the trypanosome causative of the disease surra, from an infected animal to a healthy one. The same author (*7*) in 1914 reported the direct transmission of anthrax through the biting of *T. striatus*. Morris (*9*), in 1918, transmitted anthrax through the bite of *Tabanus* sp.

Boerner and Hartman (*1*), in 1914, in dealing with methods of suppression of anthrax in certain counties in Texas, were firmly convinced that tabanids had much to do with the epizootic. The anthrax bacillus was found by them in cultures of bacteria taken from the mouth parts, the feet, and from the ingested blood of these flies. In addition to this evidence, it was found that from 90 to 95 per cent of all the animals dying of anthrax in the five counties adjacent to where the flies were captured had local swellings on parts of the body most often attacked by this fly. Furthermore, unusual abundance of the fly was coincident with widespread epidemics of the disease.

In the Antelope Valley of California, where anthrax has often occurred, the same coincidence has been noted. It is a common opinion in the valley that the flies have much to do with transmission of the disease.

In 1906, the spread of surra among quarantined cattle imported from India was attributed by Mohler and Thompson (*8*) to the agency of *Tabanus atratus* Fab., some of which were feeding on the animals.

INFESTING MAN.

In Utah, during recent years, there have been several cases among human beings of what is known as the "deer-fly disease," commonly called that because histories of the cases usually revealed a bite from what is commonly known as the deer fly. That this fly, *Chrysops discalis*, is the carrier of the disease to man has long been suspected by physicians who have dealt with the malady. It remained, however, for Francis and Mayne (*2*) of the United States Public Health Service to demonstrate clearly the transmission of the disease by this insect.

ANTELOPE VALLEY.

Antelope Valley, lying partly in Nevada and partly in California, is about 23 miles long north and south (fig. 3). The valley is from 2 to 5 miles in width. It lies among the foothills of the east side of the Sierra Nevadas, about 65 miles south of Reno. The altitude at Topaz in the middle of the valley is about 5,400 feet.

CLIMATE.

The climate is typical of the semiarid valleys of the eastern slope of the Sierras. There is not sufficient rainfall to grow crops without irrigation. The growing season is comparatively short, being

[2] Numbers (*italic*) in parentheses refer to "Literature cited," p. 36.

limited to about five months of the year. In midsummer the days are hot but the nights cool, while the winter is extremely cold.

The West Walker River, rising among the snow-capped mountains to the west, flows through the valley, and it is from this stream that most of the water is obtained for the irrigation of the hay meadows and alfalfa fields which produce the principal crops.

Most of the valley, approximately 100 square miles, is owned and operated by one large land and cattle company with general headquarters at Reno. Several other large ranches in Nevada and California are operated by the same company. A few smaller and independent ranches are to be found along the west side of the valley. The headquarters of the large ranch are at Topaz, which is the name of the post office.

The major outputs of the valley consist of beef cattle, sheep, and wool. About 5,000 cattle, 18,000 sheep, and 1,000 horses and mules are wintered at the company ranch. As a necessary adjunct to the

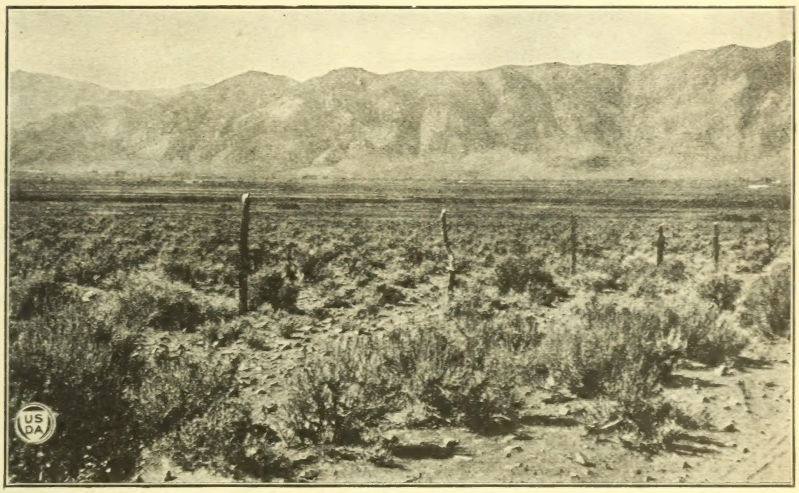


FIG. 3.—Antelope Valley of Nevada and California, from eastern side of valley looking southwest.

stock raising about 7,000 tons of hay are produced, 1,000 of which are alfalfa. Several hundred acres of oats and wheat were grown on the ranch in 1919.

IRRIGATION.

The summer precipitation in the valley being insufficient, the crops are absolutely dependent upon irrigation. On each side of the valley are two main supply ditches. Except during brief intervals for repair, water runs in these ditches continuously for irrigation in the summer and for watering stock in the winter. The sides of the valley slope considerably and from fields on these areas the irrigation water drains away rapidly. This waste water for the most part drains onto the more level part or floor of the valley and there finds such inadequate outlet that it accumulates in wide swampy areas and sluggish sloughs. Much of the floor of the valley is flooded from ditches to hasten the luxuriant growth of wild hay

and pasturage. This flooding, together with the wastage from higher areas, makes the floor of the valley a succession of swamps. In certain parts these swamps and sluggish channels are grown to tules. Areas slightly more elevated are grown to water grass and moss. In the fall of the year, when irrigation is discontinued, much of this semiswampy area affords wonderful pasturage; during the wet season it affords breeding places for an abundance of tabanids.

At the northwest corner of the valley proper, nature, fortunately in some respects and unfortunately in others, left a reservoir. In this low spot, from the irrigation of the northwestern part of the valley, has accumulated a body of water known as Alkali Lake, about a mile long and one-half mile wide (fig 4). The shores of this lake and the swampy area adjacent are choice breeding places of *Tabanus punctifer* and *T. phaenops*, the former being found abundant in moist humus near the edge of the water. The lake has no outlet.

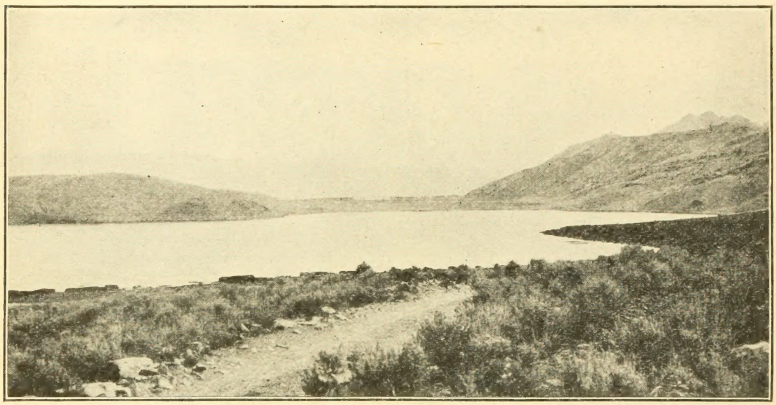


FIG. 4.—Alkali Lake, Antelope Valley, looking south towards Topaz, Calif.

The intervals between irrigations of the more sandy land of the higher slopes of the valley average about two weeks. The flooding of the floor of the valley has no cessation until about the middle of the summer, when the water becomes more scarce. Then it is diverted into the higher ditches for the irrigation of the more important crops.

The ultimate destination of the overflowing wastage is the West Walker River, which runs through the valley. Provision of adequate drainage channels for this wastage is, as will be discussed later in this paper, one of the solutions of the tabanid problem.

BREEDING METHODS AND EQUIPMENT.

On account of the cannibalistic habit of tabanid larvæ, it was found necessary in rearing to isolate each larva. Glass fruit jars of 1 pint capacity were used for this. The disk of the cover was discarded and in its place a circle of galvanized wire gauze or screen was soldered into the ring (fig. 5). This arrangement admitted plenty of air and completed the isolation. In each jar was placed mud or débris similar to that from which the larva was taken in

nature. Water was added from time to time to approximate the natural amount of moisture. For food, small snails and earthworms were placed in the jars. The worms were usually cut into pieces 1 to 2 inches in length. The snails were introduced alive. Of the two the snails were of the most value as food. The larva would crawl into the shell and devour the entire contents. In making observations on the progress of the development of the larva the entire contents of the jar was dumped onto a white granite platter, where the search for the larva could be carefully made. Often it was found completely concealed within the shell of a snail.

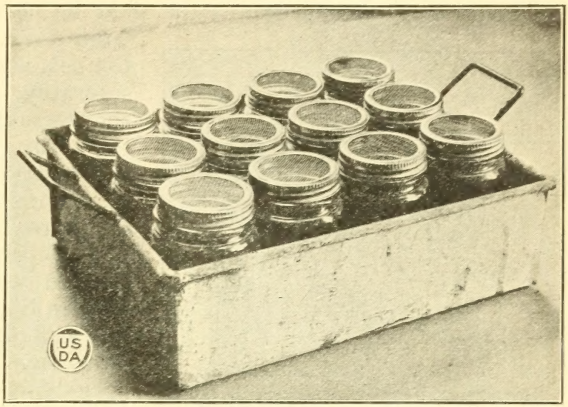


FIG. 5.—Jars used for rearing horse-flies.

The small one-room building constructed for the laboratory was widely open on each side and properly screened (fig. 6). This afforded good circulation of air.

At the beginning an attempt was made to duplicate soil temperatures and to provide a more uniform temperature than that which would result from leaving the jars exposed to the air. Galvanized-iron pans 4 inches deep and large enough to contain 12 jars were used. Water several inches deep was kept in the pans. This pro-

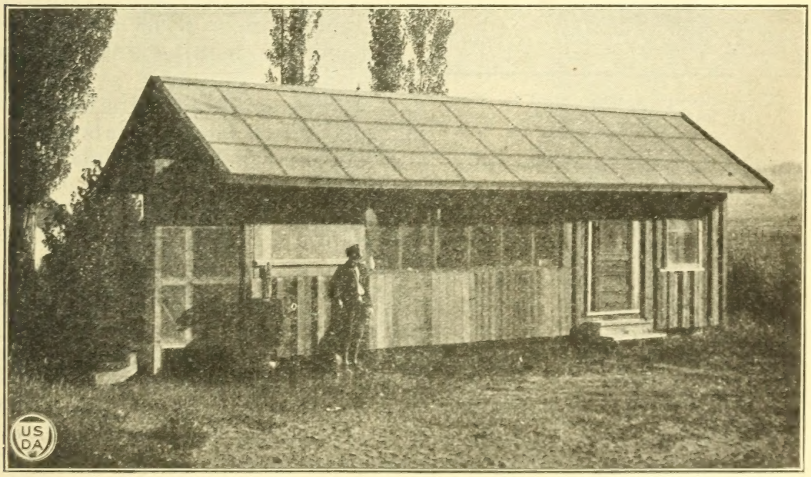


FIG. 6.—The field laboratory for horse-fly investigations at Topaz, Calif.

cedure was soon abandoned because time and facilities were not available to determine its value and because successful rearings could be made without it.

When the larvæ were in the prepupal stage or had already pupated no more water was added and the media usually became quite dry before the adults emerged. It was found that the adults would soon denude themselves if left more than an hour or so in the rearing jars.

Tabanid eggs collected in the field hatched very readily in the laboratory, but it was found that the period of incubation was considerably shorter in cases where they were exposed to high temperatures in direct sunlight. The eggs were taken to the laboratory on a portion of the vegetation or object to which the mass adhered and suspended over about a half inch of water in a glass vial an inch in diameter. A cotton stopper was placed in the vial to prevent any intrusion of predators or escape of emerging parasites. Upon hatching, the larvæ dropped to the water. *Tabanus punctifer* larvæ would remain near the surface; *T. phaenops* larvæ would remain more deeply submerged. The number of eggs was determined in most cases by counting the larvæ. In the case of badly parasitized egg masses the eggshells had to be counted. Egg masses of *T. phaenops* often became detached and dropped into the water, where they failed to hatch. This can be avoided largely by leaning the vials at an angle.

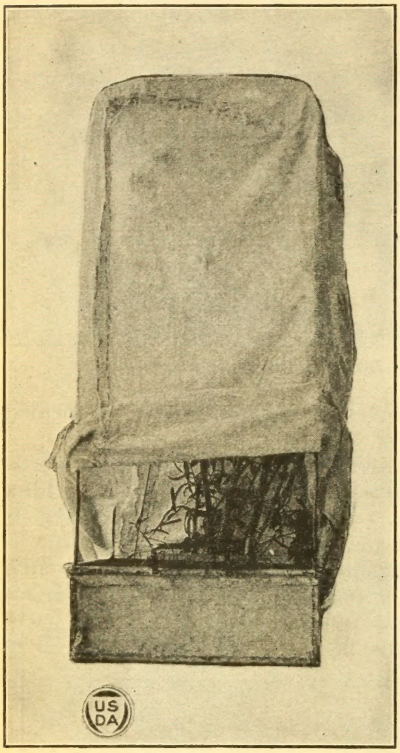
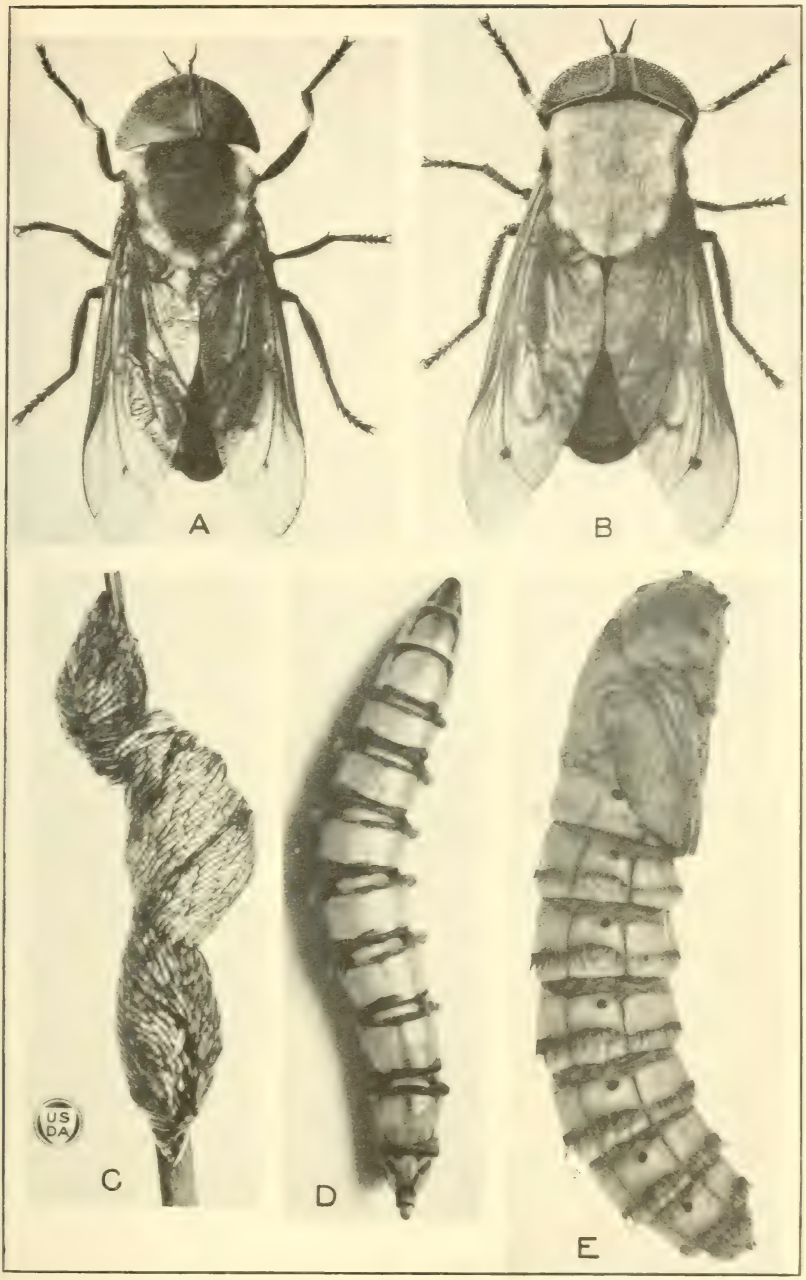


FIG. 7.—Oviposition cage used in securing horse-fly egg masses.

Larvæ collected in the field were placed with mud in vials or jars, several being in one container, and were carried to the laboratory with very little fatality.

OVIPOSITION CAGES.

It has been found very difficult to get *Tabanus punctifer* and *T. phaenops* to bite a host in captivity. A screen-wire cage 5 feet high and 10 feet square was constructed partly over water near a sluggish stream. The cage contained water plants and other vegetation upon which it was hoped the flies might oviposit. A calf 7 months old was placed in the cage September 1, 1917. About 300 flies (*T. phaenops*), including 8 or 10 males, were captured and released in the cage. The last flies were introduced September 11. On September 15 all were dead. No eggs were found and no flies were observed biting the calf. They appeared to be occupied in a constant effort to escape. Ovipositions were obtained, however, in a smaller cage (fig. 7). A rearing pan of galvanized iron 4



TABANUS PUNCTIFER.

A, adult male; *B*, adult female; *C*, egg masses, three masses upon a single stem; *D*, full-grown larva (living larva photographed by means of a special automatic flashlight device developed by S. B. Doten); *E*, pupa.

inches deep and 11 by 14 inches horizontally formed the base of the cage. A wire frame 18 inches high fastened to the corners of the pan supported the cheesecloth tent which was used for the caging. The lower end of the tent was closed by tying it with a string around the perimeter of the pan. A piece of soil containing moss, grass, and humus from a swamp was cut to the shape of the pan and placed within it, the grass and other plants extending into the tent above. Water nearly to fill the pan was added, and maintained at this level. Straws and pieces of sheet cork were placed around the edge of the island and slightly above the water.

FIG. 8.—The feeding cone, showing method of capturing full-fed horse-flies.

FEEDING CONE.

Since *Tabanus phaenops* and *T. punctifer* are very reluctant to bite any host in captivity, it was necessary to capture some individuals which had been well fed in nature, in order to secure ovipositions. This was accomplished by the aid of a wire cone of ordinary house screen 3 inches in diameter and 8 inches long (fig. 8).

The point of the cone was cut off so as to allow an opening of about three-fourths of an inch. A gentle horse led into the field was good bait. After the fly had pierced the skin of the host and had begun feeding it was not easily disturbed. The large opening of the cone was then placed over it and so held. When the fly withdrew, which it usually did not do until it had become filled with blood, it was by careful manipulation made a captive. Through the small end of the cone it was transferred to a vial, carried to the laboratory, and released in the small oviposition cage previously described.

Rubber boots, hip length, were very essential. The extra-length boots, aside from their use in deep water, protected the knees when kneeling in swampy places in search of eggs and larvæ.

SPECIES INVOLVED.

The species of greatest economic importance in Antelope Valley are *Tabanus punctifer* (Pl. I) and *T. phaenops* (Pl. II). Other species found there are *T. insuetus* O. S. (Pl. III), *T. intensivus* Townsend, *T. productus* Hine (Pl. IV, *D*, *E*), *Chrysops coloradensis* Bigot (Pl. IV, *F*), *C. discalis* Will., *C. proclivus* O. S., and *C. surdus* O. S.

TABANUS PUNCTIFER Osten Sacken.

Description of Adult.

Tabanus punctifer (Pl. I), popularly known as the big black fly, is the largest fly commonly found in the Western States. Its general appearance is black, with the top of the thorax yellowish white.

The species was first described by Osten Sacken in 1875 (*11*), and because the publication is not generally available the author's description is quoted here in full:

> Male and female. Head (♂) large, with distinctly separated large and small facets; front (♀) broad (broader than in *T. nigrescens*); frontal tubercle large, somewhat ill defined in outline and rather flat; antennæ black, projecting angle of the third joint rectangular; face brownish; palpi black. Thorax and scutellum, above, whitish or yellowish white, in consequence of a dense pollen, covered by a pubescence of the same color; pleuræ, pectus, abdomen and legs black, or dark brown; front tibiæ white at the base for more than one-third of their length. Wings brownish, especially on their proximal half; costal cell brown; a faint brown cloud on the crossvein at the base of the second posterior cell, which is not prolonged on the crossvein at the base of the third posterior cell; a dark brown round cloud at the bifurcation of the third vein. Length, ♂, 19 mm.; ♀, 19–20 mm. * * *.
>
> This species is not unlike *T. stygius* Say, but is a little smaller, and easily distinguished by the white color of the base of the front tibiæ, the blackish or brownish, and not ferruginous brownish, wings, the absence of distinct white lines on the thorax, etc. The head of the male is much larger than in *T. nigrescens*, and the large facets occupy much more surface.

Unfortunately the males (Pl. I, A) are seldom seen in nature and are hard to capture. A good number were reared from larvæ, and these males differ markedly from the description given by Osten Sacken in the color of the dorsal vestiture. The dorsum of the thorax of the male, instead of being clothed entirely with yellowish white, has only a margin of that color, about 1.6 millimeters wide, surrounding a central area of black. This black spot appears in strong contrast with the whitish margin and is a very striking sexual distinction.

Distribution.

Osten Sacken gives the following:

> West of the Rocky Mountains; Utah, Sonora, Calif., etc.; also Colorado (G. Ridings); seems to be a common species.

Specimens have been taken at Hunt, Ariz.; El Centro, Bishop, Bridgeport, Topaz, Chico, and Alturas, Calif.; and Deeth, Lovelock, Reno, and Carson City, Nev. The junior author has seen them in eastern Montana at Powderville, but has not collected them there. They were quite abundant in Antelope Valley and along the east side of the Sierra Nevada Mountains north of Bishop, Calif. In 1916 they were reported to have been exceedingly abundant at Wellington, Nev.

On account of less abundance, *T. punctifer* is considered of less economic importance than *T. phaenops*.

Abundance.

From reports and observations, *Tabanus punctifer* was more abundant in the summer of 1916 than during the three years fol-

lowing. August 25, 1916, 25 flies of this species were seen at one time attacking a pony.

The earliest appearances recorded for *T. punctifer* were May 28, 1919, at Lovelock, Nev., and at Topaz, Calif. On June 7, 1919, several were captured in Slinkard Valley, adjacent to and several hundred feet higher than Antelope Valley. The flies are most abundant during July and the first three weeks in August. During the last week in August they begin to decline in numbers and the latest one recorded was seen September 21, 1916.

Feeding Habits.

The females (Pl. I, *B*) of *Tabanus punctifer* attack horses and cattle eagerly, usually biting the animal along the back and, when numerous, on the jaws and neck. During the investigation there was only one instance of this fly biting man. On August 20, 1919, while the junior author was collecting at Alkali Lake, one bit him on the back through a heavy khaki shirt. The bite was exceedingly painful, being comparable to the thrust of a needle. The fly was captured in the hand. Horses make a most determined resistance to them. Cattle resist them less energetically; a cow lying down was observed to remain passive while a fly fed to repletion.

On July 29, 1919, *T. punctifer* was observed trying to feed upon carcasses. During the forenoon several attempted to feed upon the carcass of a cow dead for three days. Apparently they were unable to puncture the skin, because after several attempts they flew away. During the afternoon the carcass of a cow that had died only about an hour before was found. During the period of about one-half hour 14 *T. punctifer* were observed actually feeding on the carcass. This animal was suspected of having died of anthrax. On August 18 the carcass of a horse dead for several days was found in a ditch. The carcass lay half in water. Three *T. punctifer* attempted to feed, but the one captured and examined contained no blood. On one occasion a female attempted to feed upon a sack of forge coal. After inserting her mouth parts through the meshes of the burlap two or three times she flew away.

On account of the excitement and interruption usually attending a feeding of this fly in nature it was very difficult to ascertain the actual length of time required for the ingestion of a full meal of blood. One accurate record is of special interest. On September 21, 1916, one was observed to alight upon a cow which was lying down. The cow was perfectly calm and the fly fed to apparent satiety in 11 minutes and 10 seconds.

Captured females refused to bite in captivity, as did also reared females, save in one case. Female No. 128 emerged August 21, 1919. On August 22 she was placed on a horse, a glass breeding jar being held inverted over her. She did not try to feed. On August 26 she was again placed on a horse. After brushing her labellum for half a minute with her forelegs she began trying to feed. She punctured the skin in four places, not feeding until the fourth puncture, where she fed for a period of 10 minutes, apparently continuously. While feeding her hind legs were extended in the air nearly parallel with the body; the first and second pairs of legs supported her on the

horse. During the feeding four droplets of clear fluid exuded from the anus. After feeding she again brushed the labellum with the forelegs and tried to fly. Her abdomen appeared to be fully distended with blood. This species was never observed among the stock much earlier than 4 a. m. or later than 5 p. m. It was most abundant and active between 10 a. m. and 3 p. m.

Both males and females of this species in captivity were very fond of sweets. They fed eagerly on after-dinner mints and on sugar solution.

Mating And Egg Development.

No mating of *Tabanus punctifer* was observed. The reared female No. 128 which emerged August 21 and which fed on the host on August 26 was then placed in an aquarium cage with several reared males. On September 4 the female was found dead lying on top of the soil in the cage. A *T. punctifer* larva was devouring the contents of her abdomen, which contained egg masses partly developed.

Oviposition.

No oviposition of this species was obtained in captivity. Egg masses were easily found in nature. They are attached to bulrush stems, coarse grasses, trunks of small trees (fig. 9; Pl. I, *C*) which grow in or hang over water, and occasionally to overhanging timbers of irrigation boxes. The distance of the eggs above the water varies from 1 to 3 feet.

Prof. A. C. Burrill reports one observation made in Idaho of *Tabanus punctifer* depositing a mass of eggs during "a hot August day, on the second strand of a barbed-wire fence midway between two posts and within 3 feet of water in the irrigation ditch parallel to the fence."

The senior author, on August 9, 1918, observed a female (No. 7693) of this species which had just finished ovipositing and was still in position, head downward. She was engaged in brushing the end of the abdomen over the mass, apparently distributing the cement with which the mass of this species is usually covered. The fly was not frightened away at the approach of the observer. The stem upon which she was resting was broken off and she was watched at close range for some little time before she flew away.

The egg masses were found most abundantly during August around the shore of Alkali Lake (fig. 9).

Egg Mass.

The egg mass of *Tabanus punctifer* (Pl. I, *C*) varies considerably in shape and size, depending upon the dimensions of the surface to which it is attached. When this surface is wide and flat the perimeter of the base of the mass is somewhat elliptical in shape, about 15 millimeters long and 10 millimeters wide. A mass attached to a slender object has a much narrower base. The eggs (fig. 10, *a*) are arranged in from three to five layers parallel to the base of the mass. Each layer has a perimeter slightly smaller than the layer preceding it, so that the mass has a pyramidal appearance. One mass of three layers measured 5 millimeters in thickness. Relative

to the base of the mass the eggs slant at an angle of about 45°, the mass usually being placed so that the distal end of the eggs points downward. A freshly laid mass is almost snow white. In a few hours this deepens to a whitish gray and becomes progressively darker, until on the third or fourth day it is nearly light brown. After hatching, the mass is light to dark brown. The mass is covered with a cement which helps to hold the eggs firmly together and possibly gives them some protection against predators and parasites, though the eggs of this species are heavily parasitized, as is discussed on page 31. The number of eggs in a mass varies from 200 to 800. The number of eggs was ascertained by counting the issuing larvæ, and since the masses in all but one case were parasitized the count of larvæ did not accurately indicate the number of eggs. The mass not parasitized contained 582 eggs. From one slightly parasitized mass, No. 7694, 701 larvæ were counted.

FIG. 9.—Along western shore of Alkali Lake, showing location of egg masses of *Tabanus punctifer*.

LARVA.

Before hatching the larva of *Tabanus punctifer* is ready to cast the skin of the first instar. Through the transparent eggshell can be seen the second instar within the exuvium of the first. Most of the larvæ when hatching carry the first exuvium to the water, where the molt is completed. The larvæ remain near the top of the water with the siphon to the surface.

DESCRIPTION OF THE FIRST EXUVIUM.

The first exuvium is 2 millimeters long. There are 11 body segments, 3 thoracic and 8 abdominal. The thoracic segments taper to the narrow diameter of the head capsule. The anal segment terminates with the pointed siphon, which, like the mouth parts, is shed when the larva molts. To many of the skins the molted siphon and mouthparts are hanging. Each segment, except the eleventh or anal, is provided around its anterior margin with from 5 to 10 rows of short spines. Along the venter this strip of spines consists of about 10 rows and along the dorsum of about 5 rows. The anterior end of the first thoracic segment is armed with spines for about one-third of its length. These spines and the ones in the spinose strips around the other two thoracic segments appear

to be longer and slightly less opaque than those on the abdominal segments. In front and at each end of the anal aperture are numerous spines. On the front half of each segment are scattered bristles. On each side of the midventral line of each thoracic segment is a small tuft of 3 to 4 bristles varying in length. Dry mounts are the most satisfactory for studying these skins.

SECOND INSTAR.

Soon after the first molt of *T. punctifer*, the larva (fig. 10, *b*) is 2.7 to 3 millimeters long; the general color is creamy white; preserved in alcohol it becomes a pale yellow. The segmentation is the same as in the first instar. As in the full-grown larva, the head capsule telescopes into the two front thoracic segments. Each abdominal segment has a strip of yellow pile around both the anterior and posterior margins. The second and third thoracic segments have the yellow pile on only the anterior margins. The first thoracic segment into which the head capsule telescopes has yellow pile over the anterior and extending back over nearly half the segment. Each of the seven abdominal segments on its anterior margin has 6 tubercles, 3 in a line each side of midventer about equally spaced, the outer one being slightly below the midlateral line. The tubercle nearest the midventral line is circular, the outer two being oval. The tubercles are beset with stout spines and aid in locomotion. On the venter of each thoracic segment about midway are two tufts of 3 or 4 bristles like those described on the exuvium of the first instar. All the segments have numerous scattered bristles on the anterior half.

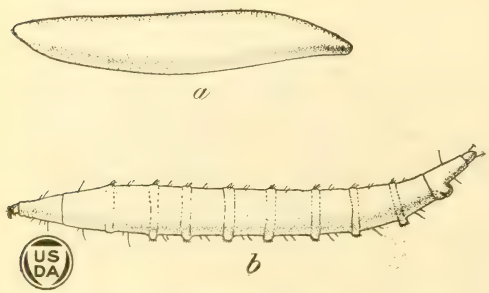


FIG. 10.—*a*, Egg of *Tabanus punctifer*; *b*, larva of *T. punctifer* after first molt. Greatly enlarged.

The anus is elliptical in shape, with long axis transverse. It has a margin of yellow pile which extends in a triangular area to near the midlateral line.

The siphon, slightly shorter than the anal segment into which it telescopes, is tubular and of constant diameter for two-thirds of its length. The posterior third narrows slightly to its circular end. The anterior end of the siphon has a wide margin of yellow pile. Where the tube narrows are four pairs of bristles, one pair on each side ventrally and one pair on each side dorsally. Several bristles are seen near the end around the opening.

In the anterior part of the anal segment above the anus Graber's organ (*5*) appears as two pairs of dark-colored globules. The anterior pair is the larger. They are dark brown and opaque. This observation was facilitated by using specimens cleared in hot five per cent caustic potash for 45 minutes. For study best results were obtained from alcoholic mounts. It was found very difficult to mount the specimens in balsam without great distortion.

DESCRIPTION OF MATURE LARVA.[3]

(Figs. 11–13; Pl. I, *D*)

Larva (mature) about 47 millimeters long, 5 millimeters wide; subcylindrical, elongate, tapering anteriorly and posteriorly; head well developed; thoracic segments 3; abdominal segments 8; two swollen, rounded anal lobes located ventrally on eighth abdominal segment, on each side of a longitudinal, almost vertical, anal slit (fig. 11).

Head.—Head (fig. 13) porrect, deeply retracted with about four-fifths of head capsule invaginated, entire head capable of complete withdrawal into thorax. Length of head capsule about 4.5 millimeters; width about 1 millimeter; sides parallel. Head capsule smoothly chitinized; ground color pale yellowish. Dorsal surface of capsule with long and rather broad, anteriorly and posteriorly attenuate, dark brown stripe on each side of epicranial suture; this stripe is accompanied, posteriorly and exteriorly, by a much shorter but almost as broad, spindle-shaped, dark-brown spot, and also medianly and

[3] By Adam G. Böving, Bureau of Entomology.

interiorly, very close to epicranial suture, by a fine dark-brown line. Lateral surface of head capsule with a dark fine line from middle of the main dorsal stripe to the point where tip of cardo attaches. Processes at anterior part of head capsule, and anterior tentorial arm (*D*), heavily chitinized, dark brown. Dorsally and laterally the head capsule is formed by fusion of the immovable labrum, the clypeus, the epistoma, the membranous bristle-bearing projection partly representing the frons, and the epicranium; posteriorly the capsule is closed by a convexly rounded wall limiting the occipital foramen behind, and ventrally it is bridged by the large median gular plate, limiting the occipital foramen in front. Occipital foramen ventral, large. All anatomical elements of the cranium are recognized principally by those criteria by which they are characterized throughout the entire insect class, sutures being present only to a very limited extent. Labrum about one-fifth the length of entire head capsule, very narrow, compressed, keel shaped, with dorsal surface bent downward like the bill of a bird of prey, whitish, membranous, with the inside enforced by one pair of long splinter-like chitinizations; posteriorly united with clypeus. Clypeus flat, ovate, almost circular, diameter about one-third the length of labrum; shiny yellow, with posterior one-third somewhat darker. Epistoma (*D*) characterized by socket with which mandible articulates dorsally; developed as separate sclerite, forming a strong frame on each side of clypeus; anteriorly prolonged as a slender process, which projects close to and along the side of posterior half of labrum; posteriorly flattened into a triangular plate. From the anterior margin of this latter (*D*), the aforementioned articulating socket projects on the inside, reaching forward as far as half the length of the slender process along the labrum; posteriorly and also on the inside of the epistoma the long, chitinous rodlike anterior tentorial arm attaches, extending posteriorly into the interior of the cranium, reaching and merging into the lateral border margin of the occipital foramen (*K*). Frons not developed as a definite structure. Epicranium occupying main part of entire head capsule, dorsally divided by the longitudinal median epicranial suture. Each epicranial half with process containing fossa for ventral mandibular condyle (*D*). Laterally and anteriorly the chitinous margin of the epicranium runs obliquely upward and outward from the base of process for dorsal mandibular articulation to the tip of process for ventral mandibular articulation. Articulating basal membranes of antenna and of mandible united with a membranous element, probably corresponding to angulus frontalis (a well-developed part of frons in many insect larvæ, for instance, the beetle larvæ), forming together a forward-extending structure very similar to an inflated bag (*I*). Dorsally this bag is attached to the anterior lateral chitinous margin of the epistoma; ventrally, along a V-shaped line, to the exterior part of basal margin of mandible; numerous conspicuous hook-like bristles set distally on the top; a short, straight, thick chitinous rod present in the ventral wall between the patch of bristles and the ventral articulating condyle of the mandible (*B*). The tendon of the mandibular exterior (=abductor or extensor) muscle developed from inner end of rod. Hypostomal margin of epicranium rather short, longitudinal, and curved, reaching from process for ventral mandibular condyle to the small cusp where the end of the cardo articulates. Gula a comparatively large plate, twice as long as wide, almost as long as labrum, shaped like a coat-of-arms, anteriorly with emargination; bridging the epicranial halves behind the posterior ends of the cardines. Tentorium represented only by the anterior tentorial arms mentioned and described above; tentorial bridge or posterior tentorial arms not developed. Optic spot single, dark, placed in the middle of oblique lateral line of epicranium. Antenna distinct, three jointed, with very small distal joint; long, slender, cylindrical middle joint placed anteriorly on the brownish, chitinized, somewhat arcuate, very flattened and posteriorly extended basal joint. Mandible compressed, vertical, separated into a distal and proximal division. Distal division (described by authors as the entire mandible) strongly chitinized, falciform, movably connected like the blade of a penknife with the proximal division; proximal division consisting of a

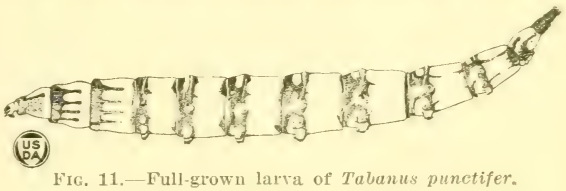


FIG. 11.—Full-grown larva of *Tabanus punctifer*.

large fleshy top region, developed as receiver for the distal division, and of a much smaller, strongly chitinized basal region; this latter contains the processes with the mandibular dorsal fossa and the ventral condyle, which articulate, respectively, with the dorsal and ventral articulating processes from the antero-lateral margin of the head capsule. The tendon of the interior mandibular muscle (=abductor or flexor mandibularis) extends from the inner corner of the basal region, and the exterior mandibular muscle (=abductor or ex-

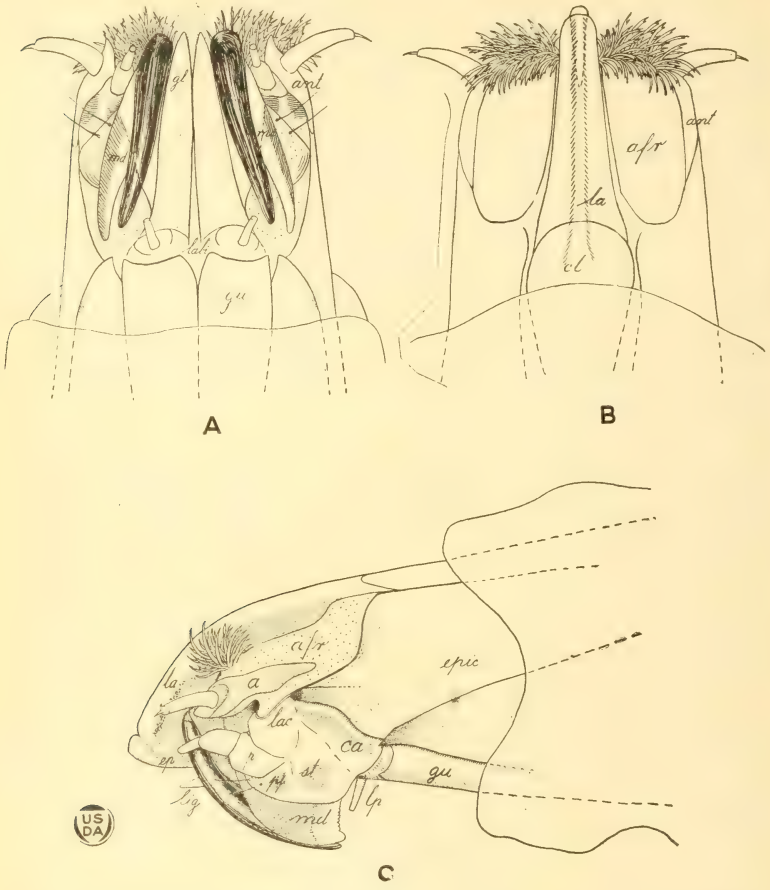


FIG. 12.—Mature larva of *Tabanus punctifer*. *A*, Anterior part of head from below; *ant*, Antenna; *gl*, glossa; *gu*, gula; *labi*, submentum, mentum, and stipes labii fused into small transverse membranous area. *B*, Anterior part of head from above: *afr*, Angulus frontalis; *ant*, antenna; *cl*, clypeus; *la*, labrum. *C*, Anterior part of head from side: *a*, Antenna; *afr*, angulus frontalis; *ca*, cardo; *ep*, epipharynx; *epic*, epicranium; *gu*, gular plate; *la*, labrum; *lac*, lacinia; *lig*, ligula (glossa); *lp*, labial palp; *md*, mandible; *p*, maxillary palp; *pf*, maxillary palpifer; *st*, maxillary stipes. Drawn by H. B. Bradford under supervision of Adam G. Böving.

tensor mandibularis) is, as previously mentioned, attached to the chitinous rod in the membranous process formed by the combined mandibular articulating membrane, membranous angulus frontalis, and antennal articulating membrane. Maxilla attached to epicranium along the hypostomal margin. Cardo and stipes hardly separated. Cardo whitish, entirely membranous, not much smaller than stipes. Stipes yellowish, divided into three sclerites of subequal size and more or less of subtriangular shape; one sclerite ventral and posterior, probably stipes maxillae; the second, ventral and anterior, possibly palpifer; the

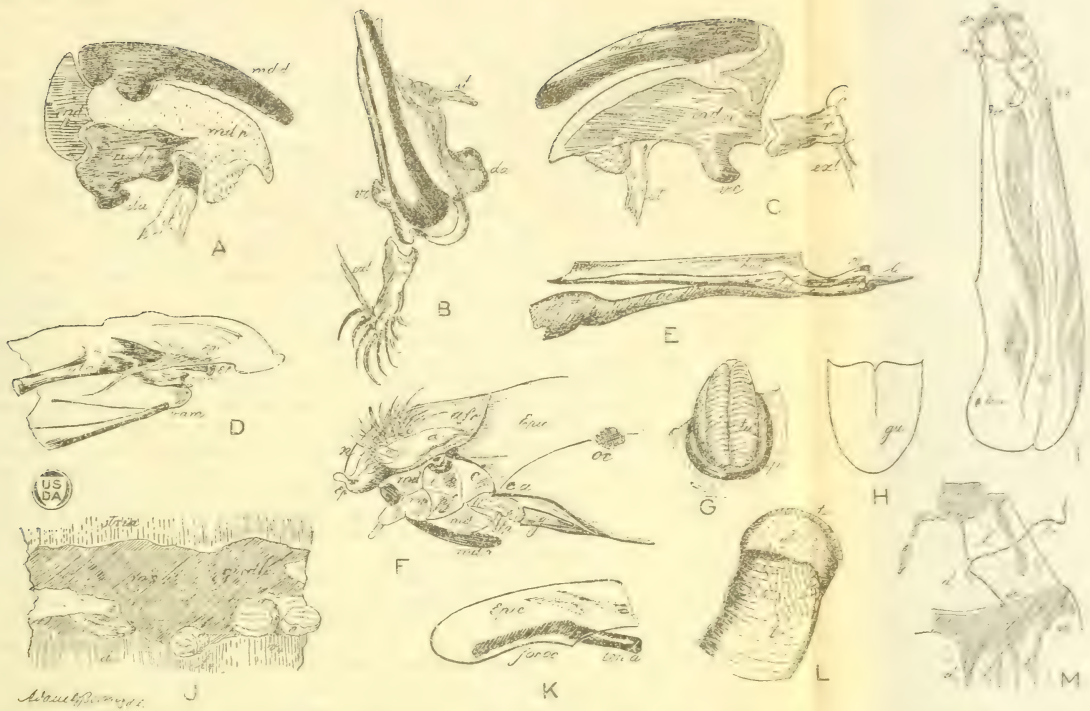


FIG. 13.—Mature larva of *Tabanus punctifer*. *A*, Mandible, dorsal side, appearing as the interior side in larvæ with vertically placed mandible as the present larva: *da*, Dorsal articulating process; *it*, tendon of interior mandibular muscle (or flexor); *mdp*, proximal part of mandible; *mdd*, distal part of mandible. *B*, Mandible, top view: *da*, Dorsal articulating process; *ext*, tendon of exterior mandibular muscle (or extensor); *it*, tendon of interior mandibular muscle (or flexor); *r*, rod in articulating membrane of mandible; *vc*, ventral condyle. *C*, Mandible, ventral side (appearing as the external side on account of the vertical position of the mandible): *ext*, Tendon of exterior mandibular muscle (or extensor); *it*, tendon of interior mandibular muscle (or flexor); *mdd*, distal part of mandible; *mdp*, proximal part of mandible; *r*, rod in articulating membrane; *vc*, ventral condyle. *D*, Head capsule, anterior portion from inside: *ata*, Anterior tentorial arm; *dam*, process for dorsal mandibular articulation; *cl*, process from epicranium extending alongside of labrum; *ep*, epipharyngeal skin; *vam*, process for ventral articulation of mandible. *E*, Paragnaths and hypopharyngeal chitinizations: *hch*, Hypopharyngeal chitinization; *li*, part of ligula (the right glossa removed); *oe*, oesophagus; *pg*, paragnath (=maxillulæ=paraglossa). *F*, Anterior part of head from the side: *a1*, Basal joint of antenna; *a2*, second joint of antenna; *a3*, apical joint of antenna; *afr*, angulus frontalis; *c*, cardo; *ca*, articulation of cardo; *ep*, epipharynx; *epic*, epicranium; *g*, gular plate; *l*, lacinia; *li*, ligula; *lp*, two-jointed labial palp; *md*, proximal portion of mandible; *md**, distal portion of mandible; *mp*, maxillary three-jointed palp; *n*, labrum; *oc*, ocellus; *pf*, palpifer. *G*, Spiracle of eighth abdominal segment: *p*, Peritrema, the chitinous frame of spiracle; *tu*, air tube of spiracle. *H*, Gular plate (*gu*). *I*, Entire head from above and tilted a little to the right: *af*, Angulus frontalis; *at*, antenna; *cl*, clypeus; *e*, epistoma with *tea*; *es*, epicranial suture; *m*, maxilla; *oc*, ocellus; *tea*, anterior attachment of tentorial arm; *tep*, posterior attachment of tentorial arm. *J*, Fourth abdominal segment, right portion, flattened out: *a*, Ampulla; d_4, dorsal region; l_4, lateral region; *ms*, white spot where muscle is attached on inside; v_4, ventral region. *K*, Posterior part of head capsule: *epic*, Epicranium; *foroc*, foramen occipitale; *tena*, anterior tentorial arm (posterior portion). *L*, Spiracle and terminal part of trachea of eighth abdominal segment: *atr*, Atrium, the hair-filled air chamber below the air tubes; *h*, hair; *tr*, trachea (upper half removed); note the enforcing spiral in the wall; *tu*, air tube. *M*, Inside of prothorax and mesothorax, right portion, flattened out: *d*, Dorsal region; *l*, lateral region; *sp*, spiracle; *tr*, trachea; *v*, ventral region. (Drawn by Adam G. Böving.)

67887°—24. (Face p. 16.)

third, dorsal, with strongly chitinized concave, crescent-shaped marginal thickening, possibly lacinia. Maxillary palpus 3-jointed; all joints subequal in length, basal joint almost square, twice as wide as second, and second joint twice as wide as the apical one. Mentum, submentum, and basal region of labium representing stipes labii and palpiger labii, fused into a small, transverse, entirely membranous area in front of the gular plate and between the posterior parts of the cardines (*F*).[4] Labial palp small, with two yellowish, chitinized joints; basal joint very low, twice as wide as apical joints; apical joint comparatively long, cylindrical, slender, about same length and width as the apical joint of the maxillary palpus. Ligula as long as gular plate, half as wide; white and entirely membranous; apically bifid, forming two glossæ. The paragnaths of Snodgrass and Crampton (=the maxillulæ of H. I. Hansen and G. H. Carpenter=the paraglossæ auctorum) present behind the dorsal or buccal surface of glossæ; each paragnath forming a chitinized, small, well-defined sclerite, standing up as a longitudinal, short, triangular, compressed tooth (*E*). The buccal floor smoothly chitinized between the paragnaths. The hypopharyngeal chitinization anteriorly fused with the floor chitinization, but rising to a somewhat higher level; prolonged into a single, dorsally concave, ventrally convex rail which extends backward through the cranial cavity above the œsophagus and to which strong retractor muscles are attached. Epipharynx distally formed by a slightly chitinized, elongate-subovate minor part, proximally by a rodlike, anteriorly upward-curved major part. This latter part joins with the hypopharyngeal chitinization above the entrance to the œsophagus and at the point where the rail-shaped internal chitinization begins.

Segments of thorax and abdomen.—Prothorax and 8th abdominal segment conical with obtuse apices, respectively pointing forward and backward, subequal both in length, about 2 millimeters, and in width, about 1.75 millimeters. Mesothorax and metathorax subequal in size and general shape to the 7 anterior abdominal segments, each about 5 millimeters long and about 5 millimeters wide. Segments, in parts finely longitudinally striate, white anteriorly with a rather conspicuous dark girdle containing white spots corresponding to muscle attachments on the inside; metathorax and abdominal segments also with posterior dark, but less conspicuous, girdle. On each thoracic segment the border between the dorsal and lateral regions is marked by a dark, longitudinal, posteriorly pointed stripe from the anterior girdle; a similar marked border between the lateral and ventral regions; in the prothorax the lateral region is uniformly colored without any median longitudinal stripe, in the mesothorax and metathorax 2 such stripes are present (*M*); in the prothorax the ventral region has a single median longitudinal stripe, in the mesothorax and metathorax no ventral stripes. Abdominal segments without stripes, but located in the anterior girdle, dorsally with one low ampulla on each side, laterally with one large ampulla, ventrally with two large ampullæ. Ampullæ reduced in the eighth segment.

Spiracles.—Thoracic spiracles, one pair, very small, usually concealed within a vertical cleft, located laterally in the segmental boundary line between the prothorax and mesothorax. Abdominal spiracles, one pair, large, with a vertical spiracular slit, placed closely together at the end of a telescopically movable, posteriorly protruding, dorsal prolongation of the eighth abdominal segment.

Pupa.[5]

The pupa (fig. 14, *A*, *B*; Pl. I, *E*) is 28.5 to 33 millimeters long. The width of the thorax is 6 millimeters. Just after transformation the pupa is pale yellowish throughout. When nearing transformation to adult, the head turns black, and under the binocular the eye facets may be plainly seen through the skin. Dark areas also appear upon the prothorax, and the entire body is somewhat darker.

The head portion bears at the lower extremity of the anterior aspect, arranged upon opposite sides of the median line, two rounded, wedge-shaped, chitinous projections. Immediately laterad of these is a prominent tubercle, evidently the palpal sheaths. Posterior to the wedge-shaped teeth and somewhat remote from them are 2 prominent rounded chitinous tubercles, 1 at each

[4] The gular plate of the orthorrhaph larvæ has by recent authors been termed "submentum"; this interpretation is not correct, as the submentum always is located in front of the posterior end of the cardines, the gula behind.

[5] Description by J. L. Webb, Bureau of Entomology.

side of the median line, each bearing a bristle; considerably posterior to these are 3 smaller nonchitinous tubercles, the anterior one on the median line, the two others at each side and slightly posterior. Postero-laterad to these upon each side is a tubercle bearing a bristle. On latero-ventral aspect of prothoracic region posterior to wedge-shaped teeth 2 tubercles occur upon each side, each bearing a bristle.

Thoracic spiracle with rima broadly curved. In the female no hook occurs, but in the male a distinct hook occurs at the anterior end.

Each abdominal segment except the first and eighth bears a complete double circlet of bristles, the posterior circle being the longest. On the eighth, or anal segment, there is a dorso-lateral fringe of bristles, and in the male a continuous fringe of bristles on the ventral aspect, but in the female the ventral fringe is interrupted on the median line. Terminal teeth of anal segment about equal in size.

The descriptions of pupa and larva were made with the aid of a binocular microscope.

Life History.

EGG.

The egg of *Tabanus punctifer* averages 2.7 millimeters long and 0.5 millimeter thick (fig. 10, *a*). The basal part of the egg is more blunt than the distal part, which tapers to a small dimension. The shell has no thickenings or ridges. There is no operculum. When deposited the egg is snow-white.

INCUBATION.

Four accurate records were obtained of the incubation period of *T. punctifer*. They are given in Table 1.

Table 1.—*Incubation period of Tabanus punctifer.*

Date.	Egg mass.			Temperature during incubation.			Date.	Egg mass No. 8715.	Temperature during incubation.		
	No. 7693.	No. 7694, Breeding No. 1.	No. 7694, Breeding No. 2.	Max.	Min.	Mean.			Max.	Min.	Mean.
1918.				°F.	°F.	°F.	1919.		°F.	°F.	°F.
August 9	(1)	(1)	(1)	84.0	43.0	63.5	Aug. 13	(1)	92.0	42.1	67.0
10				85.0	43.5	62.2	14		93.0	44.2	68.6
11				84.0	42.0	63.0	15		95.0	45.3	70.1
12				87.0	37.0	62.0	16		96.0	55.7	75.8
13				82.0	44.5	63.2	17		93.0	49.0	71.0
14				79.0	40.0	59.5	18		94.0	49.0	71.5
15				79.0	42.0	60.5	19		96.0	44.2	70.1
16				77.0	33.0	55.0	20		98.0	48.3	73.1
17				71.0	35.0	53.0	21	(2)	98.0	48.8	73.4
18				74.5	38.0	56.2					
19				75.0	38.0	56.5					
20		(2)		80.0	33.5	56.7					
21				80.5	34.0	57.2					
22				73.5	34.5	54.0					
23	(2)		(2)	79.0	38.0	58.5					
Incubation period (in days)	14	11	14					8			
Average daily mean temperature	°F. 58.4	°F. 58.9	°F. 58.4							°F. 71.7	

[1] Deposited. [2] Hatched.

The mean temperature on the day of oviposition was not figured in the average mean.

No. 7694 was placed in direct sunlight on August 16 and kept there each day until hatching. No record was kept of the actual

temperature in the sunlight. With the higher mean temperature during the incubation of mass No. 8715, the incubation period was much shorter. The summer of 1919 was unusually hot. It is probable that in nature a few of these egg masses are in direct sunlight very much of the day. Hence the average incubation period in Antelope Valley is probably between 10 and 14 days. When hatching the larvæ burst open the shell somewhere near the distal end, and crawl actively out and drop into the water over which they have hatched.

LARVA.

No material or data were obtained to indicate the number of molts of *T. punctifer*. Mitzmain (7) gives three instars for *T. striatus* Fab., but on account of the vast difference in size between the second instar and the full-grown larva of *T. punctifer* there can be little doubt that there is an intermediate instar.

PUPA.

Accurate records were obtained on the pupal periods of 22 specimens. These are given in Table 2.

TABLE 2.—*Pupal periods of Tabanus punctifer.*

No.	Date of pupation.	Date of emergence.	Pupal period.	Sex.
			Days.	
6879–1	July 7, 1919	July 27, 1919	20	Female.
6896–1	July 8, 1919	July 25, 1919	17	Do.
7648–9	July 31, 1918	Aug. 28, 1918	28	Do.
10	Aug. 1, 1918	.....do.....	27	Male.
13	July 8, 1918	July 24, 1918	16	Do.
129	July 29, 1919	Aug. 19, 1919	21	Female.
128	July 28, 1919	Aug. 21, 1919	24	Do.
140	Aug. 4, 1919	.....do.....	17	Do.
141	Aug. 5, 1919	Aug. 23, 1919	18	Do.
142	July 25, 1919	Aug. 10, 1919	16	Male.
143	Aug. 8, 1919	Aug. 25, 1919	17	Do.
145	Aug. 9, 1919	.....do.....	16	Do.
147	Aug. 12, 1919	Sept. 1, 1919	20	Do.
148	.....do.....	Aug. 30, 1919	18	Female.
150	Aug. 13, 1919	Sept. 1, 1919	19	Do.
163	Aug. 16, 1919	Sept. 4, 1919	19	Do.
164	Aug. 18, 1919	Sept. 11, 1919	24	Male.
165	Aug. 16, 1919	Sept. 5, 1919	20	Female.
167	Aug. 17, 1919	Sept. 3, 1919	17	Male.
168	.....do.....	Sept. 9, 1919	23	Female.
179	Aug. 21, 1919	Sept. 13, 1919	23	Male.
182	Aug. 24, 1919	Sept. 22, 1919	29	Female.

The average pupal period was 20.4 days. The average period for males was 19.6 days; for females, 21 days. It will be noted that the period was longer during the latter part of August and September when the temperatures were considerably lower. The temperatures are not given because they would not accurately represent temperatures of the soil in which the larvæ pupated.

Out of a large number of larvæ of *T. punctifer* reared from the egg only four pupated, and only three of these emerged as adults. Table 3 gives the duration of development.

TABLE 3.—*Developmental period of Tabanus punctifer.*

Date hatched.	Date of pupation.	Period of larval development.	Date of emergence.	Pupal period.	Sex.	Total period of development.
1917.		*Yr. Mo. Da.*	1919.	*Days.*		*Yr. Mo. Da.*
September 23	July 13, 1919	1 9 20	Died			
Do	July 1, 1919	1 9 8	July 18	17	Female	1 9 25
Do	July 29, 1919	1 10 6	Aug. 19	21	Female	1 10 27
Do	July 1, 1919	1 9 8	July 19	18	Male	1 9 26

Thus the developmental period in some cases is nearly two years. The larvæ were isolated in the rearing jars previously described. During the winter months they were cared for at the State experiment station at Reno, Nev.

HABITS OF THE LARVA AND PUPA.

Tabanus punctifer larvæ are cannibalistic, and in rearing them isolation is necessary.

Larvæ of this species were sometimes found in marshy areas and in the mud of sloughs. Several large ones were found in the loose gravel and sand a little above the edge of the water in an irrigation ditch. The ditch carries water all summer and part of the winter. The water is clear and cool and flows rather rapidly. These larvæ were found most abundantly, however, around the shore of Alkali Lake. They were almost always found a little above the water line, where waves kept the shore wet. Many were found in very coarse gravel and others in finely divided and decaying vegetation washed up on the shore. Always they were in very wet material. The water in this lake is somewhat alkaline, there being no outlet. A few fish are found in the lake.

In the rearing jars pupæ of *T. punctifer* were found near the surface of the medium, where there was less moisture. The pupæ were rather difficult to find in nature. On August 20, 1919, two pupæ were found along the west shore of Alkali Lake. They were about an inch below the surface in loose, fine gravel, fairly moist, approximately 8 feet away from the edge of the water, on a rather gradually sloping shore. The season being a dry one, the water line had been slowly receding, and possibly pupation took place slightly nearer the edge of the water. From these pupæ a male and a female emerged August 27, or seven days after collection. Hence they were pupæ of about 12 days when found.

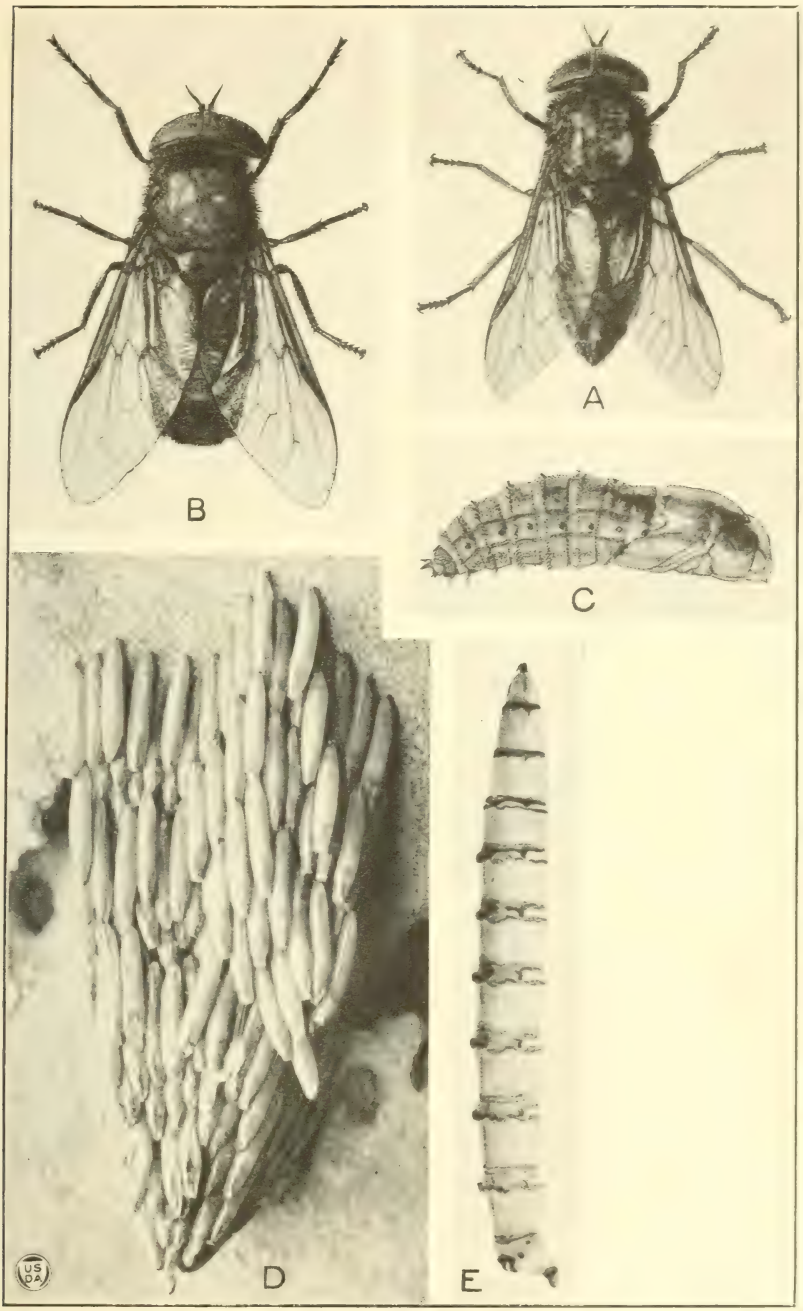
TABANUS PHAENOPS Osten Sacken.

DESCRIPTION OF ADULT.

Tabanus phaenops (*10*) is commonly known in Antelope Valley as the greenhead. The eyes are bright green, the thorax glossy black, and the abdomen broadly red on the side. (Pl. II, *A*, *B*.) It was described by Osten Sacken (*11*) in 1877. His description follows:

TABANUS PHAENOPS n. sp.—A *Therioplectes* of the same group with *T. sonomensis*.

Female.—Grayish-black; sides of the abdomen red; wings hyaline, no distinct brown cloud on the bifureation [bifurcation] of the third vein; antennæ black. Length 13–14^{mm}.



TABANUS PHAENOPS.

A, adult male; *B*, adult female; *C*, pupa; *D*, egg mass deposited on sheet cork (greatly enlarged); *E*, full-grown larva.

Front gray, a little converging; ocellar tubercle distinct; callosity nearly square, with a spindle-shaped prolongation above; antennæ black; third joint rather narrow, its upper angle very little projecting; thorax grayish-black,

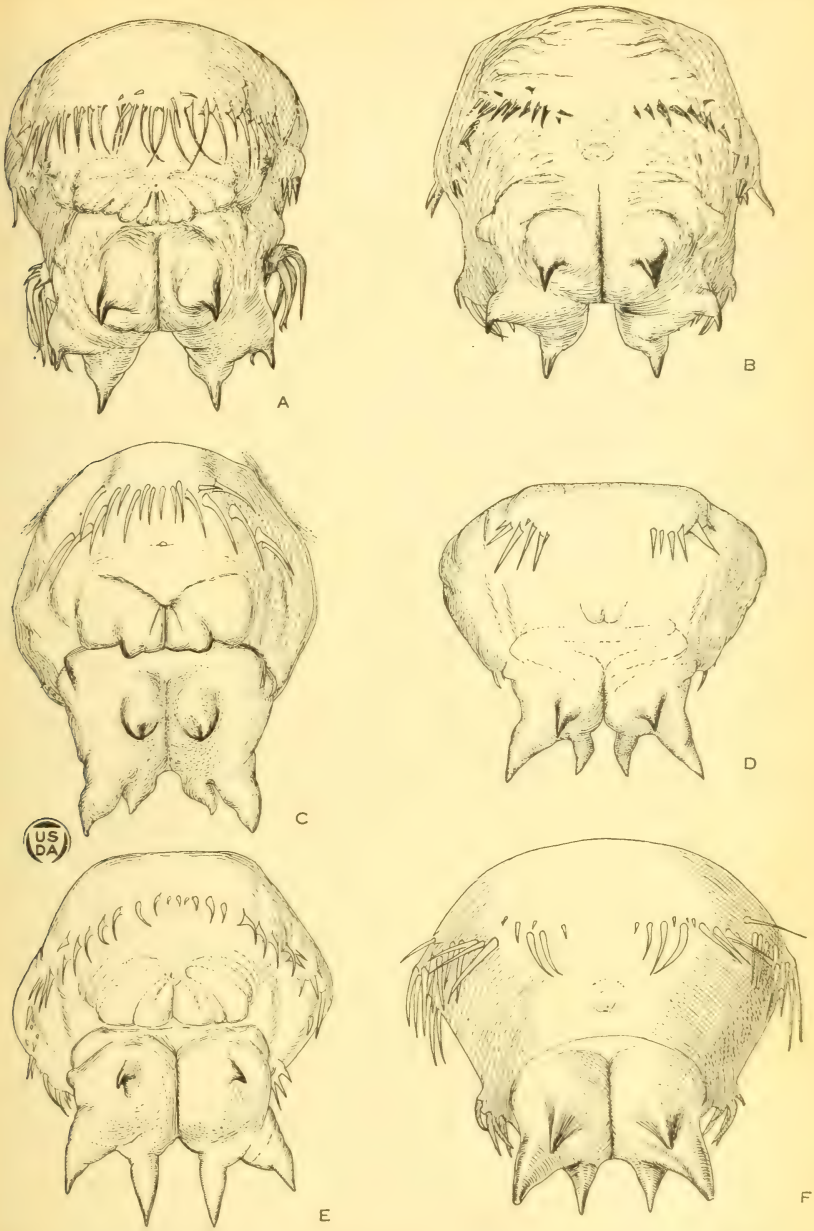


FIG. 14.—Ventral aspect of anal segment of pupa in several species of Tabanus: *A, Tabanus punctifer,* male; *B, T. punctifer,* female; *C, T. insuetus,* male; *D, T. insuetus,* female; *E, T. phaenops,* male; *F, T. monoensis,* female.

with the usual lines very faintly marked; the antealar callosity variable, reddish or dark. The black stripe inclosed between the reddish sides of the abdomen is generally rather broad, and somewhat expanded at the posterior

margins of segments 2 and 3, so as to appear jagged; the red on the sides of segments 2, 3, and 4 is clothed with a scarce and very minute golden-yellow pubescence, in the shape of faint, oblique spots; it also forms a fringe on the incisures.

T. phaenops is very like *T. sonomensis*, but it is usually a little smaller, the front is narrower, the bifurcation of the third vein is not clouded; in most, but not in all, specimens, the red on the sides of the abdomen is less extended, leaving a broader black stripe in the middle, which is expanded at the abdominal incisures, and therefore appears jagged. In shape, the abdomen is more elongated, with more parallel sides. In life, this species is easily distinguished by the color of its eyes, which are of a very bright green, with comparatively narrow purple cross-bands, much narrower than the green intervals between them; no purple in the upper and lower corners of the eye (at least, in the specimens observed).

Hab.—Webber Lake, Sierra County, Calif., July 27. Four females. Two specimens from Fort Bridger, Wyo., August 4, seem also to belong here.

Distribution.

Professor Hine (*3*) gives the distribution as "from Alaska and British Columbia to California, and specimens are also at hand from Wyoming and Colorado." In California it was found very abundant east of the Sierra Nevada Mountains as far south as near Bishop and as far north as Alturas. Specimens were taken north of Bishop, and at Bridgeport, Topaz, and Alturas, Calif. In Nevada the species is abundant near Deeth and at Wellington.

Abundance.

This is the most abundant horse-fly in Antelope Valley and at Bridgeport and Alturas, Calif. It is reported to be exceedingly abundant and a pest of great importance on the range north of Bishop, Calif. It is the most abundant species in Antelope Valley and at Deeth, Nev. In Antelope Valley these flies were more abundant in 1915 than during the four following years. They were fairly abundant in 1918, but comparatively scarce in 1919. The earliest seasonal appearance of the species was May 19, in 1918. As a rule they become gradually more abundant until the middle of July. They are abundant until the latter part of August, when usually there comes a marked reduction. They become gradually scarcer and few are seen after October 1. The latest seasonal activity observed was on October 19, in 1916. Only one specimen was observed. After the first of September, as a usual thing, they give very little trouble.

Habits of the Adult Female.

Feeding habits.

Hosts attacked by *Tabanus phaenops* are horses, mules, and cattle. Occasionally one will attempt to feed upon man. They begin soon after sunrise and gradually increase in numbers until about 10.30 a. m. From then until 4 or 5 p. m. they are abundant. The horses and cattle congregate in separate bunches about 10.30 a. m. The horses continually fight the flies with mouth, feet, and tail, not venturing to feed at all until about 4 or 5 p. m.

When these insects attack, they bite mostly on the shoulders, neck, and face, around the breast, and below the elbow (fig. 15). The

painful part of the feeding process is the puncturing of the skin. The senior author permitted a hungry fly to bite him on the arm. She made several painful punctures before the blood meal was completed. When the beak is withdrawn a little blood usually flows out and coagulates upon the skin. Animals badly bitten have a rather bloody appearance. Unlike *T. punctifer*, when this species has punctured the skin it is not easily disturbed and can often be captured in the hand. Both males and females in captivity eagerly feed upon sweet substances. They were very fond of mint-flavored candy. Females in captivity could not be induced to bite a host. As discussed on page 34, this species was attracted to and fed upon a fresh beef hide, exposed bloody side out.

FIG. 15.—*Tabanus phaenops* feeding on a horse.

HABITS OF MALES AND MATING.

Males were rather abundant in grass near swampy areas. Several times males were observed to crawl down a grass stem or other object to the surface of water and drink.

Several matings were observed in August, 1919, in a pasture where the grass was about knee high and quite dry. About 8.30 on a warm, bright morning two flies were seen mating in air about 8 feet above the ground. They were flying rapidly and soon came to rest on a stem of grass, where they were captured, still attached. Between 8 and 9 o'clock on another day four flies were observed in the air apparently all clinging together. After about 10 seconds they separated and flew away. A few minutes later two were seen in the air, but they soon separated and disappeared. Another pair mating in the air came to rest on a stem of grass, remained for a minute and a half, then separated and flew away. One pair mating in air were interrupted by two other flies, apparently of the same species. None of these were captured. Observations did not reveal whether mating began in flight or at rest.

OVIPOSITION.

Egg masses were very hard to find in nature. After a long search a few masses were finally found on stems of grass or on dried stems from 2 to 4 inches above the ground in marshy places. In cages the egg masses were found on straws and on the under side of sheets of cork an inch or two above and overhanging the water.

Egg Mass.

The form of the egg mass of *Tabanus phaenops* varies in width and length with the width or diameter of the object to which it is attached. A mass attached to a flat piece of cork was 15.6 millimeters long and 5 millimeters wide. (Pl. II, *D*.) The egg mass tapers to very narrow ends. Specimens attached to slender stems are longer and more narrow. The mass is constructed of two layers, which are parallel to the object to which they are attached. The eggs slant at an angle of about 30°. The mass when laid is white. In a day or two it is dark gray, and before hatching is black. The number of eggs in the masses hatched varied from 180 to 305, the average being 290. The eggs are apparently not covered with cement and become detached rather easily.

Incubation Period.

The egg of *Tabanus phaenops* measures 2 millimeters in length and 0.4 millimeter in width. The distal end, from which the larva emerges, tapers to a narrow diameter. The opposite end is narrowed on one side, giving the egg a rather flattened area where it is attached. The incubation period is given in Table 4.

Table 4.—*Incubation period of Tabanus phaenops.*

Date.	Egg mass No.							Temperature.		
	7661	7662	7666	7668	7673	7677	7692	Max.	Min.	Mean.
1918.								°F.	°F.	°F.
June 18	[1]	[1]						86	51	68.5
19								84	52	68.0
20								82	60	71.0
21			[1]					79	55	67.0
22								83	56	69.5
23								86	50	68.0
24				[1]				85	46	65.5
25								86	47	66.5
26	[2]	[2]						88	48	68.0
27			[2]		[1]			89	48	68.5
28								93	47	70.0
29								93	48	70.5
30				[2]				84	46	65.0
July 1						[1]		88	53	70.5
2								88	56	72.0
3					[2]			88	51	69.5
4								85	43	64.0
5								85	47	66.0
6								87	45	66.0
7								89	44	66.5
8						[2]		88	53	70.5
Aug. 3							[1]	87	45	66.0
4								88	42	65.0
5								87	33	60.0
6								86	35	60.5
7								80	38	59.0
8								83	37	60.0
9								84	43	63.5
10								85	43	64.0
11								84	42	63.0
12							[2]	87	37	62.0
Incubation period (in days)	8	8	6	6	6	7	9	.....	.....	.....
Average daily mean temperature	67.9° F.	67.9° F.	67.7° F.	68.1° F.	69.6° F.	67.8° F.	61.9° F.	.....	.....	.....

[1] Deposited. [2] Hatched.

The mean temperature on the day of oviposition was not figured in the average mean.

Larva.

Like *Tabanus punctifer*, the larva of *T. phaenops* is ready to molt upon hatching. The first exuvia are found soon after hatching in the water into which the larvæ have dropped.

DESCRIPTION OF THE FIRST EXUVIUM.

The length of the first exuvium is 2.4 millimeters. The first to seventh abdominal segments have an anterior margin of from 4 to 6 rows of spines. The neck of the first thoracic segment is armed with spines. Spines are lacking on the second and third thoracic segments. On each side of the venter, midway on each thoracic segment, is a tuft of two long and one or two short bristles, similar to the tufts on *T. punctifer*.

DESCRIPTION OF THE SECOND INSTAR.

The length of alcoholic specimens of *T. phaenops* is from 2.6 to 2.8 millimeters. The general color is white; alcoholic specimens become pale yellow. Every segment has fine longitudinal striations. The anterior end of the first thoracic segment has a collar of yellow pile covering about a fourth of the segment. Narrower margins of yellow pile encircle the anterior ends of the second and third thoracic segments. On each side of the venter midway on each thoracic segment is a tuft of three bristles similar to those in *T. punctifer* except that in *T. phaenops* the bristles are of approximately equal length. A few scattered bristles appear on each segment.

Each abdominal segment has the six-spined protuberance or prolegs and between these and continuing in a strip beyond them over the dorsum are spines slightly smaller. Around the middle of each abdominal segment are scattered bristles.

The anal segment is encircled anteriorly with yellow pile. The anus, broadly elliptical in shape, has a margin of yellow pile. The siphon, which is only half as long as the anal segment, has yellow pile around its folding anterior end. Around the opening of the siphon are numerous bristles.

DESCRIPTION OF FULL-GROWN LARVA.

The full-grown larva (fig. 16, *A*; Pl. II, *E*) is about 30 millimeters long. General color dirty gray, shading sometimes to greenish or reddish. Arrangement of propodia as in *T. punctifer*.

Prothorax: Anterior portion back of collar smooth and shiny on all aspects. Posteriorly, some striation shows on practically all aspects.

Mesothorax and metathorax: Upon each dorso-latero-cephalic area the brown of the anterior collar projects backward slightly, ending in a point.

Sides of all abdominal, and mesothoracic and metathoracic segments strongly striated. Siphon striated on all aspects. Dorsum of seventh and eighth segments fairly smooth and shiny (posterior part of eighth striated). All others striated with fine wavy lines between striæ; sixth less strongly and distinctly striated than those preceding it.

On ventral aspect of abdominal segments the striæ are broken up into irregular wavy lines, except for an area directly anterior to anus, which is smooth and shiny.

On venter of each thoracic segment are two distinct hairs placed one at each side and about midway between anterior and posterior margins of segment.

Anus surrounded by light brownish pile. Longest axis transverse. The siphon measures 0.5 millimeter.

The most characteristic features of the living larva are the dirty gray color, prominent prolegs, and strong striation of the sides of the abdominal segments, especially the anal segment.

Descriptions of larva made with the aid of a binocular microscope.

Habits of the Larva.

Larvæ of *Tabanus phaenops* hatched in a vial of water remain at the bottom of the water. The full grown larvæ of this species were

found mostly in swampy areas overgrown with grass, on or near the surface of the soil in masses of decaying vegetable matter. They were collected in the higher mountain valleys as well as in the floor of the lower valley. They were seldom found in the loose gravel by streams or in the loose humus where *T. punctifer* was so abundant around the shore of the lake.

PUPA.

(Fig. 14, *E*; Pl. II, *C*)

Length about 15 millimeters. Width of thorax 3 millimeters. Pale yellowish. Wedge-shaped teeth at anterior end not prominent. Palpal sheaths not prominent. Dorsum of prothorax smooth except for two slight rugosities, one at either side of the median line, slightly posterior to bases of palpal sheaths. Rima of thoracic spiracle broadly curved, not forming distinct hook.

Circlet of bristles on abdominal segments not double as in *Tabanus punctifer*. Dorso-lateral fringes on eighth segment normal. Ventral fringe on this segment continuous across median line. Of the terminal teeth on anal segment, the two lateral teeth are larger than the others, and these are arranged almost in a straight line with the two dorsal teeth.

Described from a single male specimen with the aid of a binocular microscope.

Table 5 contains the records of those individuals which were successfully reared from larva to adult in the laboratory.

TABLE 5.—*Pupal period of Tabanus phaenops.*

No.	Date of pupation.	Date of emergence.	Duration of pupal period.	Sex.
			Days.	
6873-1	June 2, 1917	June 25, 1917	23	Male.
6875-1	June 19, 1917	July 6, 1917	17	Female.
6884-8	July 15, 1918	July 30, 1918	15	Female.
6884-9	July 2, 1917	July 16, 1917	14	Male.
6884-12	Aug. 2, 1917	Aug. 19, 1917	17	Female.
6884-24	July 15, 1918	July 29, 1918	14	Female.
7505-1	July 15, 1918	July 29, 1918	14	Female.
8700-102	July 16, 1919	July 28, 1919	12	Male.

The average pupal period was 15.7 days. The complete life cycle was not determined. It is certain, however, that not more than one generation a year is produced.

TABANUS INSUETUS Osten Sacken.

DESCRIPTION OF ADULT

Tabanus insuetus is a small gray species with colored bands extending transversely across the eyes. (Pl. III, *A*, *B*.) Osten Sacken's description (*11*, *p. 219*) is as follows:

TABANUS INSUETUS n. sp.—Belongs apparently to the subgenus *Atylotus*. Eyes pubescent, although in the female specimens the pubescence is often hardly perceptible; in life, pale olive-green, with a single very narrow brown stripe in the middle (distinct even in dry specimens); no vestige of an ocellar tubercle; frontal callosity rather small, variable in size, narrower than the front; third antennal joint rather broad and short, with a short and stout annulate portion; palpi stout at base; first posterior cell broadly open; base of upper branch of third vein knee-shaped, in many specimens with a stump of a vein. All these characters would justify the location of the species in

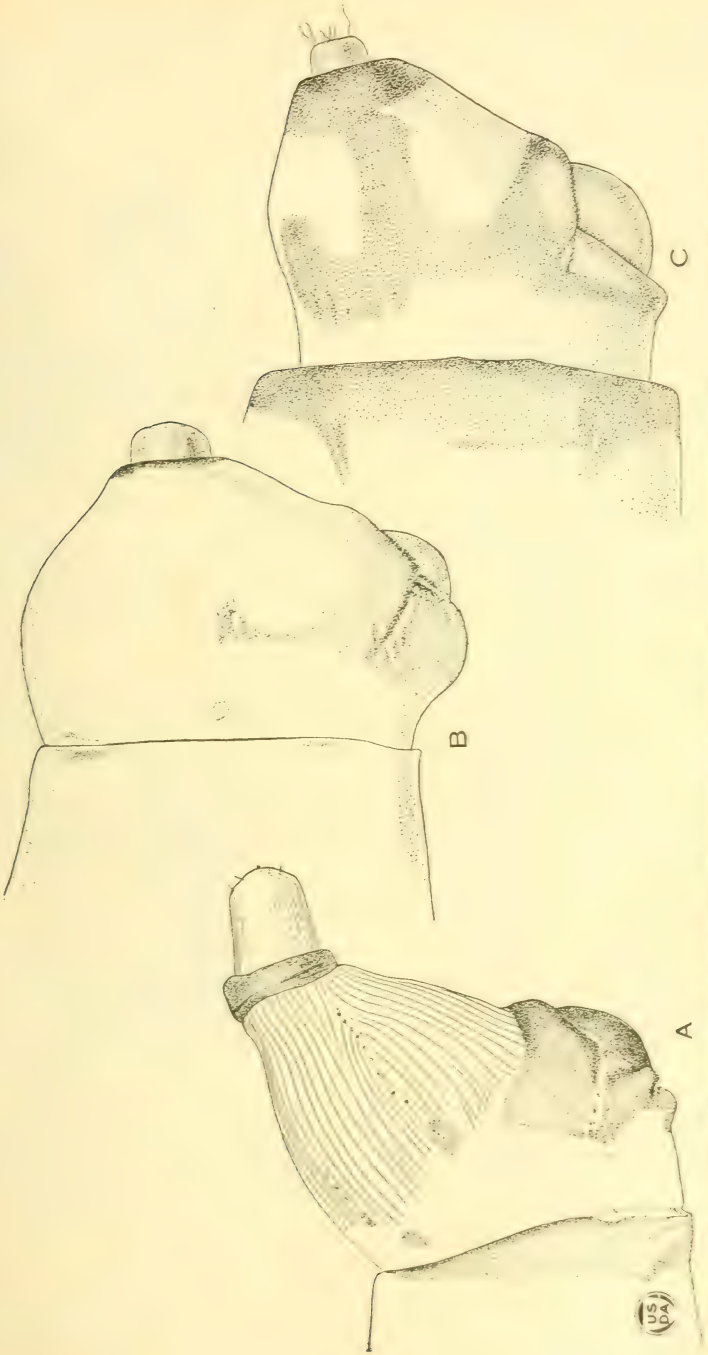


FIG. 16. Anal segment of larva in three species of Tabanus: A, *Tabanus phaenops*; B, *T. insectus*; C, *T. monoensis*.

that sub-genus; the discovery of the as yet unknown male will have to decide it.

Female.—Face and front yellowish-gray; cheeks with pale hairs; front with short black hairs; a fringe of such hairs on the upper edge of the occiput. Front broad (in most specimens; much narrower in others); frontal callosity narrower than the front, rather small, and variable in shape; usually another black, shining spot above it. Palpi short, stout at base, pale yellowish or yellowish-white, with black pile. Antennæ pale brownish-red; annulate portion of third joint sometimes, but not always, black or brown. The black ground-color of the thorax is partly concealed under a gray pollen; vestiges of longitudinal gray lines are visible anteriorly; a pale golden, sometimes whitish, appressed, rather scarce, pubescence, and black, erect pile clothe the dorsum. Pleuræ gray, with pale gray hairs. Abdomen in well-preserved specimens with three rows of yellowish-gray spots, formed by an appressed pubescence; the triangles of the intermediate row large, occupying the whole breadth of the segment; the spots of the lateral rows are oblique, prolonged laterally along the hind border of the segments (well-preserved specimens seem rarely to occur; in the worn specimens, the abdomen appears as grayish-black, somewhat reddish on the sides of the first two segments, and with but vestiges of the appressed yellowish-white pubescence and of the abdominal spots). Venter uniformly yellowish-gray. Feet variable in coloring, pale reddish-yellow with blackish (seldom pale) femora and tips of tibiæ; tarsi blackish with two posterior pairs paler at base. Costal cell and stigma more or less tinged with brownish-yellow; upper branch of third vein often, but not always, with a stump of a vein. Length 12—13 mm.

Hab.—Webber Lake, Sierra County, July 21. Twelve females.

Although not so conspicuous as either *T. punctifer* or *T. phaenops*, *T. insuetus* is a hard biter and occasionally becomes numerous enough in some of the higher mountain valleys to be troublesome to stock. It confines its attack for the most part to the legs and abdomen when attacking horses.

The larvæ are to be found without much difficulty in wet places in the upper valleys, in the top soil and humus at the base of grass roots. Abundant as the larvæ were in such situations, the eggs of this species have never been seen in nature, nor did the authors succeed in inducing ovipositions in rearing cages.

Quite a number of individuals of this species were reared from the larva to the adult stage in the laboratory. The pupal period was found to vary from 15 to 22 days.

Description of Full-Grown Larva.

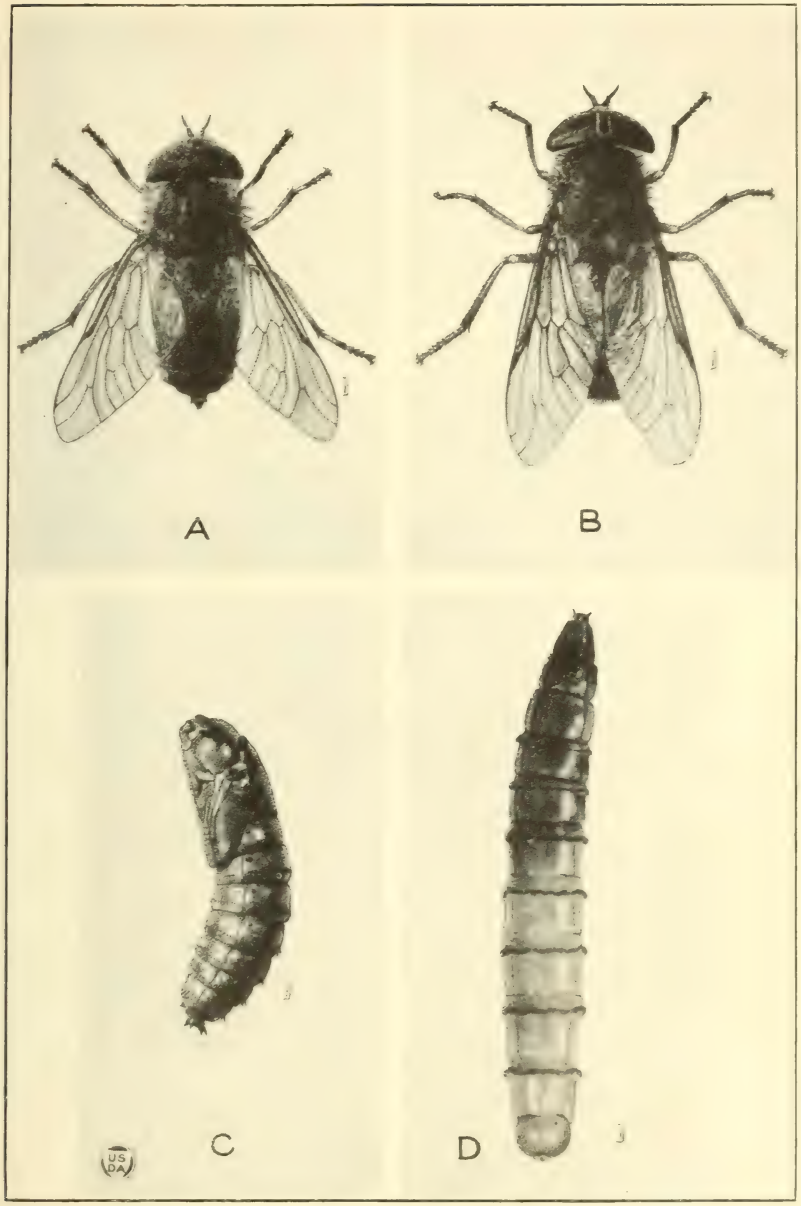
Full-grown larva (fig. 16, *B;* Pl. III, *D*) 21 to 22 millimeters long, yellowish white. Dorsal and ventral aspects of all thoracic and abdominal segments smooth and shiny. Sides of all segments, except prothorax, mesothorax, and anal segment, finely striate. On each lateral aspect of mesothorax are two deep longitudinal lines (not continuous on prothorax but showing more faintly on metathorax). Sides of prothorax smooth and shiny. Propodia arranged much the same as in *Tabanus punctifer*, not very prominent in living specimens, clothed with fine yellowish hairs which can hardly be called bristles.

Anal segment robust. Anus surrounded by an opaque surface, bearing fine yellowish pile. From each side of the anus extends dorsally a slight streak of opaque which divides just before reaching the dorsal surface into two branches, one extending posteriorly and the other dorso-anteriorly. Siphon very finely striated, extending barely beyond anal segment.

Description of Pupa.

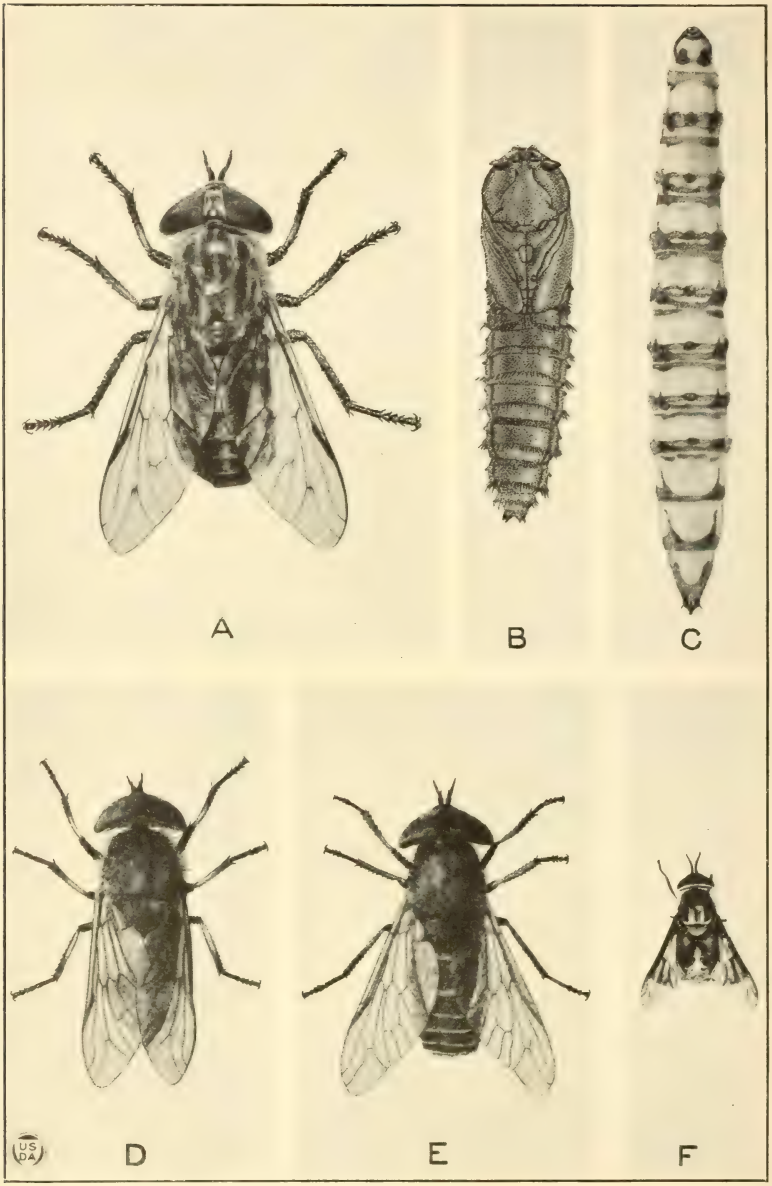
Pupa (fig. 14, *C, D;* Pl. III, *C*) 13 to 15.5 millimeters long. Width of thorax 2.5 to 3 millimeters. Color light yellow with brown spots on head and thorax.

Head region between bases of palpal sheaths rugose. Back of this two slightly elevated and rugose areas one at each side of median line. Still farther back



TABANUS INSUETUS.

A, adult male; *B*, adult female; *C*, pupa; *D*, full-grown larva.



TABANUS MONOENSIS N. SP., T. PRODUCTUS, AND CHRYSOPS COLORADENSIS.

A, *Tabanus monoensis*, adult female; *B*, pupa of same; *C*, larva of same; *D*, *Tabanus productus*, adult male; *E*, adult female of same; *F*, *Chrysops coloradensis*, adult female.

and more widely separated are two small tubercles. On ventral aspect posterior to palpal sheaths two small tubercles on each side which normally appear to bear a seta each.

In the male the rima of thoracic spiracle is curved into a hook at each end. In the female only the anterior end is hooked.

Abdominal segments 2 to 7 armed with a double circlet of bristles as in *Tabanus punctifer*, those on second segment very short. Bristles increasing in length up to seventh segment.

In the female the dorso-lateral fringe of bristles on the eighth segment just anterior to the terminal teeth is vestigial, and in the male entirely wanting. On the ventral aspect of this segment in the female the fringe of bristles is interrupted on the median line while in the male it is continuous. Of the terminal teeth the two lateral ones are most prominent. In the female the lateral teeth are arranged in a straight line with the two dorsal teeth. In the male the dorsal teeth point more directly upward.

Both larva and pupa were described with the aid of a binocular microscope.

A NEW SPECIES OF TABANUS.

A number of Tabanus larvæ collected in the mud along mountain rivulets were placed in breeding jars, and one or two adults were reared. These were found by Professor Hine to represent an undescribed species of Tabanus. (Pl. IV, *A*, *B*, *C*.) No adults of this species were found in Antelope Valley in the open.

Description of Adult.[6]

Tabanus monoensis n. sp.

Length 12 to 14 millimeters. Eyes not hairy, a small, four-sided, nearly denuded spot, narrowed anteriorly, on the frontal vertex. Wing with the furcation of the third vein and the transverse veins at the apex of the discal cell plainly margined with brown.

Female (Pl. IV, *A*): Front at vertex nearly one-third as wide as either eye, narrowed somewhat below, frontal callosity occupying the entire width of the front, shiny black, nearly square, and with a rather obscure connected line above reaching two-thirds of the distance to the vertex. Spot at vertex four-sided, plainly narrowed before, entirely separated from the eyes, very thinly pollinose and without any ocelligerous prominence such as is present in species of Tabanus with hairy eyes. Subcallus plainly pollinose but not so dense as the face. Palpi white, enlarged basally, pointed below, and clothed with black and white hair. Proboscis uniformly nearly black. Antenna brown, with the annulate portion of the third segment black, first segment prominently enlarged, nearly as wide anteriorly as the base of the third segment; second segment small, more or less hidden between the first and third; third segment widest at the base, with a small prominence dorsally, then gradually narrowing to the annulate portion of the segment, which is pointed at apex and distinctly shorter than the basal portion. Facets of the eyes of nearly uniform size throughout.

Thorax dark with gray stripes; wing hyaline with the furcation of the third vein and the transverse veins at the apex of the discal cell plainly margined with brown; some of the other veins, especially those having a transverse direction, very obscurely margined with the same color. Legs yellowish brown and black, all the femora black, front tibia yellowish brown on a little more than basal third, remainder black, middle and hind tibiæ largely yellowish brown, darkened apically, front feet black, other feet largely dark yellowish brown, darker above than beneath.

Abdomen dark in ground color with three rows of small gray spots. Hind margin of each segment narrowly gray also. Venter of abdomen partially reddish.

Male: Like the female in coloration. Compound eyes with small facets around the outside and a large area of enlarged facets on the disk. The dry specimen shows a conspicuous fuscous marking on the middle of each eye which takes the form of a somewhat irregular band across the head, widest at mid-

[6] Description by James S. Hine.

dle and gradually narrowed at each end outwardly. The specimen of this sex is deformed and there is some question about the permanence of the characters presented.

Holotype female, No. 24950 U. S. National Museum. Reared at Topaz, Mono County, Calif., by Webb and Waite, and bearing the labels "Bishopp #7652, Br. 2," and "Bred July 10, 18."

Allotype (a deformed specimen) bearing the labels, "Bishopp #7652, Br. 1*a*" and "Topaz, Cal. 6–31–18." Also in U. S. National Museum.

Nine female paratypes collected and sent in by C. F. Baker and bearing the label "Mts. near Claremont, Cal. Baker." but without date of capture.

The paratypes show some variation from the holotype in having some red under the lateral spots of the abdomen and in the redder antennæ. On account of specimens being rubbed, the body is shinier and the subcallus in some specimens is more or less denuded. The venter of the abdomen is quite broadly red in some of the Claremont specimens.

The combination of characters in the diagnosis above will serve to locate this species easily. It suggests most perhaps some specimens of *T. nivosus* Osten Sacken, but the latter lacks the spot at the vertex, and the wing veins are not so plainly margined.

Description of Full-Grown Larva.[7]

Full-grown larva of *Tabanus monoensis* about 25.5 millimeters long. Color (fig. 16, *C*; Pl. IV, *C*) white with brown markings. Seen with the naked eye, the larva is white with three brown spots on the anterior margin of each abdominal segment except the anal, which has only two. The spots upon each segment are situated in a transverse row, one in center of margin of dorsum and one at each side on dorso-antero-lateral aspect. Under the binocular microscope these brown spots are seen to be merely accentuated parts of brown bands encircling the segments as in *T. punctifer*.

Prothorax with the five principal longitudinal grooves present as in other species, but faint and not extending to posterior margin. Sides opaque on anterior three-fourths. Back of opaque area finely striate to posterior margin. Pronotum smooth and shiny. Venter with a narrow median strip of opaque; smooth and shiny on each side of this strip. Mesothorax and metathorax smooth and shiny on notum and venter. Anterior margins banded all around with brown opaque which on each side slightly extends posteriorly in four longitudinal stripes.

Abdomen with prologs about the same as those of *T. punctifer*. Sides of segments finely striate. Dorsum of sixth and seventh segments striate; on preceding segments striation on dorsum is faint. Striation faint on venter of all segments except anal, which back of anus is striated all around. Anus surrounded by fine, pale yellowish pile, bordering which is a narrow circle of brown opaque, without pile. From each side of anus a rather broad band of brown opaque extends dorsad to margin of dorsum, where it spreads posteriorly and anteriorly. Posteriorly it continues at about the same width to siphon and passes entirely around this organ. Anteriorly it goes nearly to anterior margin of segment, then broadens out on dorsum into an irregular splotch of brown color. Siphon very finely striate and bearing at tip a few setæ.

Described from specimens collected by J. L. Webb under Bishopp No. 7652, near Topaz, Calif.

Description of Female Pupa.

Length of pupa (fig. 14, *F*; Pl. IV, *B*) about 16 millimeters. Width of thorax 3 millimeters. Color yellowish brown. Tubercles on head and thorax as in *Tabanus punctifer*, though less prominent. In the one (reared) specimen available, which was probably nearly ready to transform when killed, the eyes show almost black through the skin and there are brown spots on the thorax.

Rima of thoracic spiracle curved into a small hook at anterior end.

Double circlet of bristles beginning on second abdominal segment and becoming progressively longer on succeeding segments up to the seventh. Dorso-

[7] Description of larva and pupa by J. L. Webb.

lateral fringe of bristles on anal segment normal. Ventral fringe on this segment interrupted on median line. Terminal teeth on anal segment nearly equidistant. Lateral teeth only slightly more prominent than the others.

Described from reared specimen under Bishopp No. 7652. Br. 2, larva of which was collected by J. L. Webb near Topaz, Calif.

Both larva and pupa described with the aid of a binocular microscope.

CHRYSOPS spp.

Two or three specimens of the genus Chrysops, known commonly as deer flies, are common in the region covered by this investigation. (Pl. IV, *F*.) They are, however, less important as pests than true horse-flies of the genus Tabanus. They attack horses and men quite readily in the higher altitudes, but do not appear to bother cattle to any great extent.

The eggs and larvæ are rather abundant in Antelope Valley, but for some unexplained reason adults are not found there in the same proportions. Eggs are deposited on vegetation above the water, or sometimes on the leaves of a water plant which lie flat on the water. The larvæ are to be found in the mud under the water.

NATURAL ENEMIES OF TABANIDS.

PARASITES.

Hymenopterous parasites reared from egg masses of *Tabanus punctifer* were identified as *Prophanurus emersoni* Girault.[8] Practically every *T. punctifer* egg mass collected was infested. This little parasite was observed crawling over a mass of *T. punctifer* eggs before the parent female had completed the oviposition.

The total developmental period of this parasite was determined in three masses.

TABLE 6.—*Developmental period of Prophanurus emersoni.*

Tabanid egg-mass No.	Date of oviposition of tabanid and parasite eggs.	Date uninfested tabanid eggs hatched.	Date parasites began to emerge.	Incubation period of host.	Developmental period of parasite.
				Days.	*Days.*
4693. Br. 1	Aug. 9	Aug. 23	Sept. 1	14	23
7694. Br. 1	9	20	Aug. 31	11	22
7694. Br. 2	9	23	Sept. 1	14	23

Egg mass No. 7694 Br. 1, from August 16 to August 20, was in direct sunlight out of doors. This shortened the incubation period of *T. punctifer* 3 days and the developmental period of the parasite only 1 day.

Males of this parasite would congregate around the holes from which the females were to emerge, and when the female emerged mating took place immediately.

The few egg masses of *T. phaenops* found in nature were not infested. An egg mass of *T. phaenops* was infested with *Prophanurus emersoni* in captivity. On August 5, 1918, an egg mass

[8] Determination by S. A. Rohwer.

of *T. phaenops* deposited August 3 was placed in a vial containing some hatched egg masses of *T. punctifer* on which were freshly emerged parasites. On August 9 the egg mass of *T. phaenops* was again isolated and from it on August 12 hatched 186 Tabanus larvæ. On August 27 one of the unhatched eggs was opened and a pupa of a parasite was found. Several adults of the parasites emerged August 29. Thus while eggs of *T. phaenops* are not known to be infested with any parasite in nature, this parasite was successfully reared from it in captivity.

Transportation of Parasites.

This same parasite, *Prophanurus emersoni*, was previously reared by D. C. Parman at Uvalde, Tex., from egg masses of *Tabanus hyalinipennis* Hine. On account of its abundance and the abundance of the host eggs in that locality in Texas, it was considered wise to attempt the transportation of the species from Texas to Nevada and California. A few masses of infested eggs were mailed from Uvalde, Tex., on June 25. On July 2, at Topaz, Calif., these masses from which parasites were already emerging were placed in a vial with an egg mass of *T. phaenops* deposited July 1. On July 6 the eggs of *T. phaenops* seemed to be somewhat shrunken. On July 8 the egg mass was isolated. On July 22 some of the eggs of *T. phaenops* had hatched. On September 16 five parasites had emerged and were found dead in the vial. The antennæ of another dead one were protruding through an emergence hole in the leaf to which the mass was attached.

Fig. 17.—*Bembex primaaestate*, a predator upon horse-flies.

There can be little doubt that the activity of *Prophanurus emersoni* is a very important factor in the control of *Tabanus punctifer*.

Predators.

Bembex primaaestate Johnson & Rohwer (fig. 17) is an insect similar to the "horse guard," *Monedula carolina* Drury. Hine (4) has given an account of the habits of the latter in Louisiana, and believes it to be an important enemy of horse-flies.

Residents in Antelope Valley had frequently observed the capture of horse-flies by wasps. In September, 1916, the senior author observed one pursuing a tabanid. A few minutes later one of these wasps was captured. It was identified as *Bembex primaaestate*. On July 19, 1917, a nest of this species was found in sandy gravel.

Digging with a shovel about the entrance to the tunnel, larvæ, cocoons, and a few adults of the species were found about a foot below the surface. Recently formed cocoons always had a mass of Tabanus fragments and in some cases fragments of other flies sticking to them. In the nest was also found a perfect male specimen of *Tabanus insuetus* and a perfect male *T. phaenops*. The predator, judging from reports of residents, is not annually abundant. It was rather scarce in 1916 and quite abundant in 1917. It is an interesting fact that in 1916 tabanids were more abundant than in 1917. Because of a scarcity of *T. phaenops* in the midsummer of 1917, it was believed that this predator, on account of its abundance that season, was a very effective check to the species. Bembex did not occur and *T. phaenops* was quite abundant in Bridgeport Valley 40 miles southwest and at a higher elevation.

It was decided to attempt transportation of Bembex from Antelope Valley to Bridgeport Valley. With nets 50 adults of the wasp were captured on July 23, 1917, and placed alive in two small cages about a foot square with bottoms covered with sand and gravel. In these cages they were taken hurriedly by automobile to Bridgeport Valley. About 35 survived the trip and were released at a place resembling the breeding places in Antelope Valley. Seven or eight cocoons of the species collected July 19 were placed there in gravel at the same time. Sufficient observations were not made there the following season to determine the result. In 1918 and 1919 the wasps were very scarce in Antelope Valley.

A close observation was made in 1919 of an attack on a female *Tabanus phaenops* by one of these wasps. The fly was feeding on a horse near the shoulder. Suddenly the wasp swooped down on the fly, grasped and stung her, and flew away, leaving the fly in feeding position. The fly was immediately paralyzed, so that she did not withdraw her mouthparts from the host. Her legs seemed no longer to grasp the hair of the horse and she was suspended by her mouthparts only. Removed from the horse, she seemed lifeless, except for a few quiverings of the legs. The wasp was seen no more. Undoubtedly this predator accomplishes considerable repression of the horse-flies, but in view of the data in hand can not be considered a major factor.

Stomachs of several species of insectivorous birds were examined without finding larvæ or adults of Tabanidae, a result probably not representative, since the Biological Survey has found horse-flies or their larvæ in the stomachs of no fewer than 78 species of birds.

PROTECTION OF ANIMALS.

Horses and cattle in pasture or on the range get some mutual protection from the flies by congregating so that switching of tails will brush their shoulders and heads. As previously mentioned, however, injuries result from kicking and hooking. Shade of trees, shade of buildings, and open sheds offer very little protection. It is a common observation, however, that *Tabanus phaenops* does not follow animals into the higher and drier arid lands. Stock in open range get much relief by going to sagebrush areas during the heat of the day.

The species of tabanids in Antelope Valley do not enter stables. Many individuals of *T. phaenops* and *T. intensivus* entered and remained on the walls of a tent in Slinkard Valley, and occasionally *T. phaenops* would be seen on the screen of the laboratory at Topaz, but there is no record of any tabanids in Antelope Valley biting a host within a closed building.

Horses in harness, especially those worked around the swamps or in the hayfields, are greatly harassed by the flies. The parts of the body most in need of protection are the head and neck, where *T. phaenops* prefers to bite. For this is used a hood of burlap or light canvas with holes cut for the eyes, ears, and nostrils. The cape of it extends over the neck to the shoulders (fig. 18). Often nets or burlap coverings are used over the back and rump, more especially for protection against *T. punctifer*.

FIG. 18.—Horse hoods used to protect the head and neck of the animals from horse-flies.

REPELLENTS.

Several repellents were tested, but none of them gave any marked protection. Tabanids are very determined biters, and repellents applied frequently enough to give any protection have a harmful effect on the hair and skin of the animal.

REPRESSIVE MEASURES.

POISONING TABANIDS.

While collecting tabanids on June 23, 1917, at a sheep camp in Slinkard Valley, attention was drawn to the hide of a sheep killed on the previous day. The pelt was hung to dry with the bloody side out and many tabanids were on it. *Tabanus intensivus* was most abundant. *T. insuetus* was next in abundance.

On July 6, a fresh beef hide was hung over a fence at Topaz, bloody side out, and the following solution was applied to it:

Arsenite of soda	pound	¼
Sugar	pounds	2½
Tartaric acid	teaspoonful	½
Water	gallons	1½

The hide was exposed from 10.30 a. m. to 5 p. m. No dead tabanids were found, although as many as one-half dozen flies of *T. phaenops* were seen on it at one time. Only three or four dead flies

of other species were seen. Two tabanids which ate some of the solution in the laboratory died immediately.

Poisoning tabanids by this method would be expensive and of little value.

A trap baited with bananas and set for several days caught only two females of *T. phaenops*.

No bait was found which would attract any great number of these flies into a trap. None of the species of tabanids in this region appear to congregate on buildings, as has been observed in the case of certain other species, notably in southern Florida and Louisiana. The chances of successfully trapping the species under discussion therefore seem to be very remote.

DRAINAGE.

It was ascertained that a large majority of *Tabanus phaenops* breed in areas which by drainage, not inconsistent with good agriculture, could be rendered unfit for tabanid development. Much time was spent in 1919 in determining whether tabanid larvæ were breeding in irrigated fields which drain readily or in irrigation ditches supplying them with water. No tabanid larvæ were found in well-drained fields, although earthworms were quite abundant. A few larvæ of *T. punctifer* were found in a gravel bank of a main irrigation ditch through which water flows nearly all the year. The principal land and cattle company in Antelope Vally was making plans and estimates for an extensive ditch drainage system which would drain many of the swampy areas of the valley. Such a system when completed and put into operation will render thousands of acres more productive as well as greatly relieve the tabanid situation. It can not be hoped that the drainage of the floor of the valley will eradicate tabanids, because there are springs and small streams in the foothills and higher up in the mountains which will provide limited breeding places. Of course Alkali Lake in the north end of the valley will also provide breeding places for *T. punctifer* in some numbers. It is firmly believed, however, that drainage will accomplish the ultimate control of the tabanid pest.

LITERATURE CITED.

(1) Boerner, M. H., and Hartman, Henry.
1914. Charbon disease (anthrax). *In* Bul. Tex. Sta. Board Health, v. 8, no. 2, p. 19–28.

(2) Francis, Edward, and Mayne, Bruce.
1922. II. Experimental transmission of tularaemia by flies of the species Chrysops discalis. *In* Tularaemia Francis 1921, a new disease of man. Treas. Dept., U. S. Public Health Serv., Hygienic Lab. Bul. 130, p. 8–16.

(3) Hine, James S.
1904. The Tabanidæ of western United States and Canada. *In* Ohio Naturalist, v. 5, no. 2, p. 217–248. Bibliography, p. 245–248.

(4) ———
1907. Second report upon the horseflies of Louisiana. *In* La. Agr. Exp. Sta. Bul. 93, 59 p., 37 fig.

(5) Marchand, Werner.
1920. The early stages of Tabanidæ (horse-flies). Monographs of the Rockefeller Institute for Medical Research, No. 13. 203 p., 15 pl. Bibliography, p. 200–203.

(6) Mitzmain, M. Bruin [Mayne, Bruce].
1913. The biology of Tabanus striatus Fabricius, the horsefly of the Philippines. *In* Philippine Jour. Sci., v. 8, no. 3, Sec. B, p. 197–221, 7 pl. Bibliography, p. 220.

(7) ———
1913. The mechanical transmission of surra by Tabanus striatus Fabricius. *In* Philippine Jour. Sci., v. 8, no. 3, Sec. B, p. 223–229. *Also published as* Bul. 28, Govt. Phil. Islands, Dept. Public Instruction, Bur. Agr. 11 p. Manila, 1913.

(8) Mohler, John R., and Thompson, William.
1911. A study of surra found in an importation of cattle, followed by prompt eradication. U. S. Dept. Agr., Bur. Animal Industry, Circ. 169, p. 81–97, 3 pl., 2 fig.

(9) Morris, Harry.
1918. Blood-sucking insects as transmitters of anthrax or charbon. La. Agr. Exp. Sta. Bul. 163, 15 p., 2 fig.

(10) Osten Sacken, C. R.
1875. Prodrome of a monograph of the Tabanidæ of the United States. Part II. The genus Tabanus. *In* Mem. Boston Soc. Nat. Hist., v. 2, p. 421–479.

(11) ———
1877. Western Diptera: Descriptions of new genera and species of Diptera from the region west of the Mississippi and especially from California. *In* Dept. Int., Bul. U. S. Geol. and Geog. Survey, v. 3, no 2, p. 189–354.

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
10 CENTS PER COPY

▽